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Crystal Structure

By W. L. Bragg, M.C., M.A.

Nobel Laureate: Langworthy Professor of Physics in the University of Manchester

WHEN a liquid solidifies on cooling, or when a solid is deposited from a solution, the attractions between the molecules cause them to pack themselves together into a rigid structure. This can happen in two ways: the molecules may come together in any position, or they may arrange themselves in a regular pattern. In the first case the solid is said to be amorphous; in the second case it is called crystalline. The amorphous and crystalline states may be compared to a number of men forming a crowd, and to the same number drawn up in military formation.

In the great majority of cases, the molecules, when forming a solid, arrange themselves in a regular crystalline structure, and it is only under exceptional circumstances that amorphous solids are produced. The mineral constituents of the earth's crust are almost entirely crystalline: metals are composed of a mass of small crystals, solutions deposit the dissolved body as crystals. Ice consists of a mass of water crystals, frost of the same crystals deposited by the condensation of vapour. When the molecules are given time, as it were, to arrange themselves regularly, there is always a tendency to form a crystalline structure. Glass, on the other hand, is a typical example of a class of solids called "vitreous" which show no evidence of crystalline structure.

When a crystal is not disturbed in its growth, its crystalline nature is shown by its having a number of plane surfaces meeting in straight edges, which are often symmetrically disposed. Although the extent to which these surfaces are developed may differ greatly from crystal to crystal, the angles between corresponding faces are always the same for any given substance. This can only be due to there being for every substance a regular pattern in which the molecules are always arranged when it crystallises.

This is illustrated by the two-dimensional model of Fig. 1, where the circles represent the molecules of a crystalline structure.

The figure shows how the two-dimensional "crystal" will have straight edges, formed by adding rows of

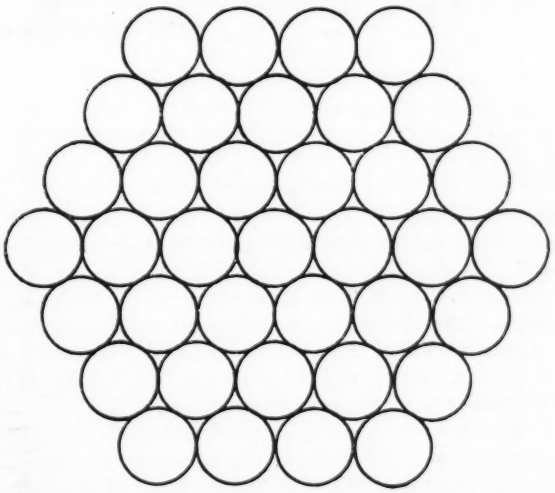


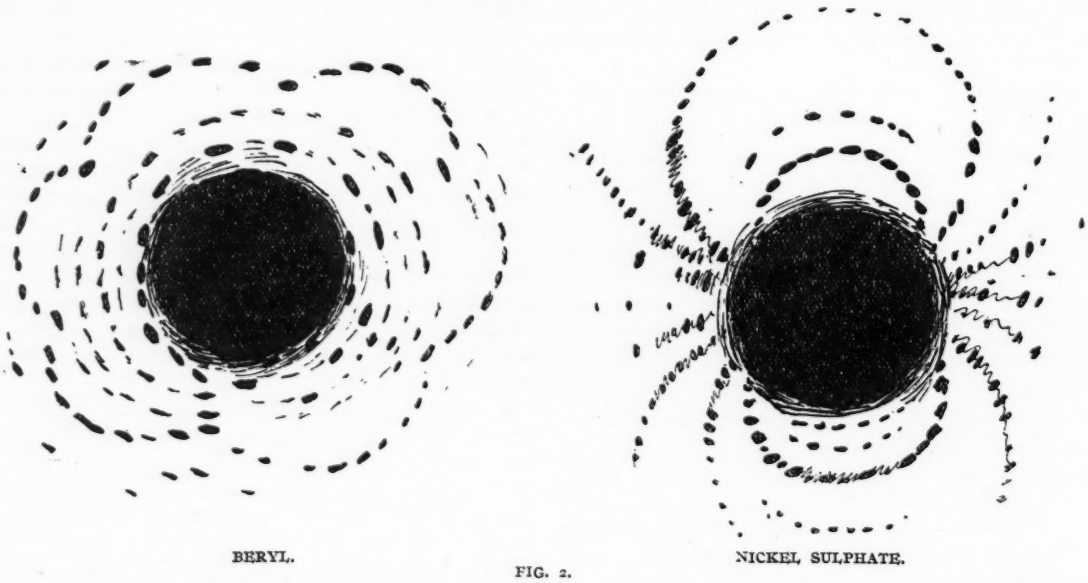
FIG. 1.—TWO-DIMENSIONAL MODEL OF CRYSTAL STRUCTURE.

molecules as the crystal develops, and if we imagine the same process to take place in three dimensions, the way in which the plane faces of a crystal grow, by the adding of layer after layer of molecules, can be pictured. It is not the possession of plane faces which

constitutes the crystal, they are merely the evidence of the internal regular arrangement.

The exact way in which the molecules of a crystal are arranged has always been a matter of great interest, but the extreme minuteness of the pattern has until recently been an insuperable obstacle to investigation. When examining small objects with a microscope the power of resolution is limited, not by the impossibility of designing a better instrument, but by the size of the light waves which we use to illuminate the object. It is impossible to see any detail of a body smaller than the wave-length of light, because the wave-trains coming from the different parts of the body cannot be distinguished from each other. The finest detail we can hope to examine with a microscope corresponds to the shortest wave-length of light we can use. Taking as unit of length the Angstrom unit, which is one hundred-millionth of a centimetre, we cannot see detail finer than about 3,000 Angstrom units. The distances separating the molecules in a crystal we know to be of the order of two or three Angstrom units, and so they are far beyond the possibility of microscopic investigation.

The discovery which opened the way towards finding how a crystal was built was made in 1912 by Laue. He was inspired to try the effect of passing a beam of X-rays through a crystal. It had already been suspected that X-rays consisted of electromagnetic waves of exactly the same nature as heat and light radiations, but with a wave-length which was one ten-thousandth that of visible light. Laue realised that such waves are smaller than the distances between the atoms in a crystal, and that they provide a source of illumination which is capable of revealing its detailed structure. In carrying out his experiment, Laue expected to get an effect on the X-rays analogous to that of a diffraction-grating on light. The diffraction-grating consists of a plate of polished metal on which a very large number of fine lines have been ruled by a diamond point at regular intervals, spaced so that there are from ten to twenty thousand lines to the inch. When light falls on such a grating, each line scatters or "diffracts" a small portion of the incident light. If light of definite wave-length is examined, there are certain directions in which the wave-trains scattered by the lines of the grating are exactly in phase with each other, the crests and troughs of the waves coinciding in position, so that they combine to form a strong diffracted beam. In other directions the waves are not in phase, and the general effect is zero. The analysis of a spectrum by a grating depends on this principle. Laue realised that a crystal provides a diffraction grating where the regular arrangement of molecules takes the place of the lines ruled on a metal grating, and where the distance between the molecules is of the right dimensions to diffract the very short X-rays.



BERYL. NICKEL SULPHATE.

FIG. 2.

The results which he obtained when he passed a beam of X-rays through a crystal are shown in Fig. 2. In his apparatus a very narrow pencil of rays fell on a small slip of crystal, and a photographic plate was placed on the far side at right-angles to the rays. The large spot in the centre of the plate is produced by the direct beam of rays, the pattern of small spots

surrounding it by the diffracted beams. The symmetry of the patterns of spots is that of the crystal used, and this shows that it is the molecular pattern of the crystal which is causing the diffraction.

This discovery has led to investigations which have greatly enlarged our knowledge both of X-rays and of crystal structure. We now know how the atoms are arranged in a large number of the simpler crystal structures; we can make a model showing their positions in the pattern, and these models explain those features of crystal symmetry which have, so far, been studied by means of the crystal's external appearance only. Using the crystal as a diffraction grating, we can, on the other hand, measure the wave-length of the X-rays, just as the wave-length of visible light can be measured with a diffraction grating.

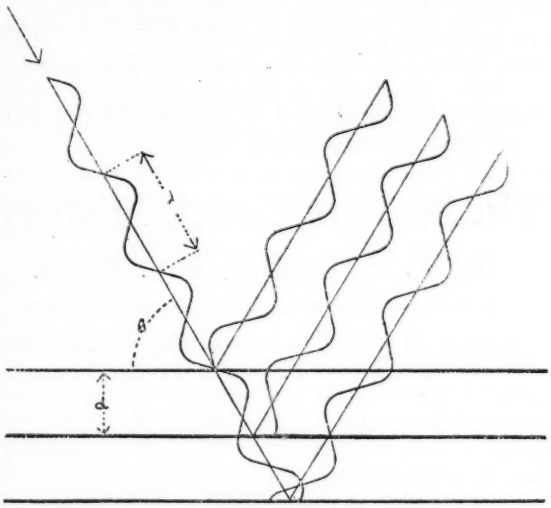


FIG. 3.—REFLECTION OF A WAVE-TRAIN FROM THE PLANES OF A CRYSTAL STRUCTURE. CONDITION FOR REINFORCEMENT $\lambda = 2d \sin \theta$.

Let us suppose that a beam of X-rays is allowed to fall on the face of a crystal. We have seen how the face may be considered as being built up, as the crystal grows, by layers upon layers of molecules arranged in planes one on top of the other. Consideration shows that each of these layers is capable of reflecting a very small proportion of the train of waves constituting the X-rays, so that a number of reflected wave-trains are produced as shown in Fig. 3.

If A, B, C, D represent the planes of a crystal structure, then waves coming in the direction of the arrow will be partly reflected at each plane. The waves reflected from the plane B have gone a greater distance than those reflected at A, those reflected at C a still greater distance, and we have here the same conditions for the interference of the waves as we have in the case of a grating and light waves. If the extra distance which is traversed by the waves reflected from B, as compared with those reflected from A, is exactly one wave-length, the two sets of waves will reinforce each other. So also will those reflected from C, D, and the other planes, and the combined reflected beam will be strong. If, however, the crystal is set at such an angle that the waves do not reinforce each other, they will interfere and reflection will not take place. The condition that reflection should take place depends on the distance between the crystal planes and on the angle at which the X-rays fall on it. Measurement of the angle when X-rays of a known wave-length are used tells at once the distance between the layers of molecules parallel to a face.

If we measure this distance for various faces of the crystal, we can find out the way in which the molecules are arranged. For instance, referring again to the two-dimensional model shown in Fig. 1, if the distances between the rows of molecules which are parallel to various faces are found, it will be clear that the arrangement of the molecules in that figure can be deduced. The measurements tell us the framework,

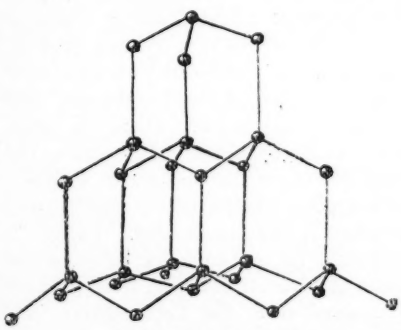


FIG. 4*a*.—ARRANGEMENT OF CARBON ATOMS IN A DIAMOND.

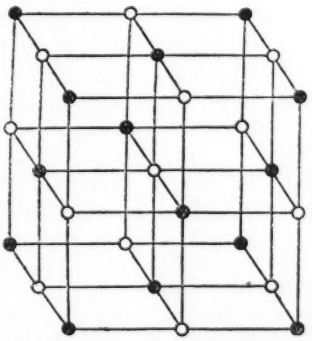


FIG. 4*b*.—ARRANGEMENT OF ATOMS IN A ROCK SALT (NaCl) CRYSTAL. WHITE CIRCLES REPRESENT SODIUM ATOMS, BLACK CHLORINE.

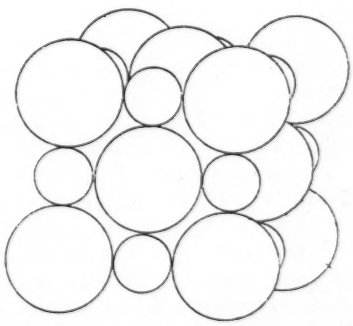


FIG. 4*c*.—MODEL OF ROCK-SALT STRUCTURE. THE LARGE CIRCLES REPRESENT SODIUM ATOMS, THE SMALL CHLORINE ATOMS.

as it were, of the structure on which the molecules are packed.

This is only the first step towards finding out the crystal structure. Each molecule is composed of a number of atoms. The positions of the atoms are found by comparing the strength of the reflected beam from any face when the path difference causing interference is one wave-length, two wave-lengths, three wave-lengths, and so on. Anyone familiar with the diffraction-grating will know that it gives, for a definite wave-length, several spectra, which are distinguished as being of the first, second or third order. The relative strengths of these spectra depend on the form of the scratch ruled on the grating by the diamond point when it is being prepared. In the case of a crystal, that which corresponds to the scratch is the molecule itself, and a study of the different orders of reflection tells us the arrangement of the atoms in the molecule. Some crystal structures worked out in this way are shown in Fig. 4.

Knowledge of these structures opens up many possibilities. Now that we know how the atoms pack themselves when they bind together, we may be able to find out the nature of the forces which cause them to do so. These forces must be of the same nature as those causing elements to combine to form chemical compounds. It is interesting to note that, in a structure such as that of rock salt, there is no evidence of the existence of the molecule in the ordinary accepted form. The sodium atom touches six neighbouring chlorine atoms, to any of which it may be considered as belonging. The same thing is found in all the crystals investigated. The diamond structure is interesting because each carbon atom touches four other atoms around it, agreeing with many other properties of carbon which suggest that carbon has four "bonds" arranged tetrahedron-wise, linking it up to the atoms combined with it.

We can carry our investigations a stage further. In the case of an element, when all the atoms are alike, that which corresponds to the "scratch" on the grating is the atom, and by examination of the different orders of reflection it may be possible to find out the arrangement of the different parts of the atom. The wave-length of X-rays is so small that we may use them to look into the interior of the atom itself.

Again, knowledge of the crystal structure tells us the distances between the atoms in a crystal, and if we think of the atoms as small hard spheres packed tightly together, we can get an estimate of the size of these spheres. In Fig. 4*c* an attempt has been made to represent the sodium and chlorine atoms with their relative sizes as found in this way.

These examples will perhaps give some idea of the vast interest now attached to the study of crystal structure. The diffraction of X-rays by crystals has not only led to a far more complete knowledge of the properties of X-rays, but it also affords one of the most promising lines of attack on the problem of atomic structure.

X-rays and Crystal Structure, by Professor W. H. Bragg, M.A., F.R.S., and Professor W. L. Bragg, M.A. Fifth edition. (London: G. Bell & Sons. 10*s.* 6*d.* net.)

Ions, Electrons, and Ionising Radiations, by J. A. Crowther, Sc.D. (Arnold, 12*s.* 6*d.* net.)

A System of Physical Chemistry, vol. i, by Professor W. C. McC. Lewis, D.Sc. (Longmans, 15*s.* net.)

The Wars of Greek History

By W. R. Halliday, B.A., B.Litt.

Professor of Ancient History in the University of Liverpool

"In one point of view," says Aristotle, "the art of war is a natural art of acquisition, for it includes hunting, an art which we ought to practise against wild beasts, and against men who, though intended by nature to be governed, will not submit." [1] He does not, however, believe in the militarist State. "Men should not study war with a view to the enslavement of those who do not deserve to be enslaved; but first of all they should provide against their own enslavement; and in the second place obtain empire for the good of the governed, and not for the sake of exercising a general despotism; and in the third place they should seek to be masters only over those who deserve to be slaves. Facts, as well as arguments, prove that the legislator should direct all his military and other measures to the provision of leisure and the establishment of peace. For the most of these military States are safe only while they are at war, but fall when they have acquired their empire; like unused iron they lose their edge in peace time." [2] Aristotle is always sensible and often profound.

Successful wars from the seventh century B.C. to A.D. 1870 have in fact provided foundations for national development. At certain stages of a nation's growth, strong government at home, combined with successful aggression abroad, promotes national solidarity and stimulates national consciousness. There is more than one analogy to be drawn between the work of the Greek tyrants [3] and that of our British Tudors. Further, the spoils of an energetic foreign policy may finance the material progress of the community. The great buildings of Syracuse, for example, or those whose ruins line the cliffs at Girgenti in Sicily, were paid for by indemnities exacted from the Carthaginian, and built by the cheap slave labour with which the over-

[1] *Politics*, I, 8, 12. [2] *Politics*, VII, 14, 22.

[3] In the sixth century B.C.

whelming victory of the Greek at Himera[1] had glutted the market. Similarly, a result of the great wars with Carthage and the Eastern Powers was to concentrate the capital of the world in Roman hands, and provide in large quantities the cheap labour of slaves. The art of war may be an "art of acquisition." Clearly, however, such wars must be limited in area and in duration. The German instinct for a short war is sound enough. The victor must not be too exhausted to profit, nor the vanquished to pay.

The great war in which a handful of Greek states faced and defeated the armies of Persia[2] was fought "to provide against their enslavement." The victory vindicated that conception of the nature of the state which the Greeks discovered, and which forms to-day the basis of Western political thought. It was a victory for the idea that the community exists in order to provide the good life for its citizens, who are free but responsible members actively participating in the life of a living whole, as against the Oriental conception of irresponsible personal government under which the state exists primarily for the benefit of the governor rather than for that of the governed.

But while it justified the conception of the state which had been developed in the small Greek communities, the Persian War put an end to the scale upon which it had been worked out. Hellenism was called upon to play an international political rôle, and the new conditions demanded the creation of a larger political unit than the city-state. Inevitably the league of maritime cities formed to complete the war with Persia became the Athenian Empire. The league ceased to be a voluntary federation from which members were at liberty to withdraw, and became an aggregate of subject states dominated politically and commercially by the mistress of the seas. And while Athens claimed, with some justice on the material side, that her empire was "for the good of the governed," her subjects had reason to regard it as "the exercise of a general despotism." For the political imagination of the Athenian did not perceive that the principle which held good for the city-state must be extended to the larger unit; that for empires to endure, subjects must become free and responsible citizens, and the whole a living organism in whose life the parts have an effective share. That, however, is a lesson hardly learned. The Romans learned it only by bitter experience, and it needed the political vision of Julius Cæsar in 49 B.C. and Augustus after 31 B.C. to extend the moral of the Social War[3] in which the Italians had extorted by armed revolt the franchise which they had failed to obtain by constitutional means. It needed, too, the rebellion of the American colonies to enlighten British imperial policy.

[1] 480 B.C. [2] 490–479 B.C. [3] 90–89 B.C.

The true background, however, to the ideals so eloquently stated in the Funeral Speech of Pericles[1] is the tyrant empire, which in its very being contradicted the fundamental quality of the Greek political ideal. And this it was which made the Peloponnesian War inevitable. The revolt of Samos against the Empire had been suppressed, but there could be no enduring peace.

Thucydides, the great Athenian historian, shows that the moral force of Greek public opinion was on the side of the adversaries of Athens, who were able to make their battle-cry the liberation of fellow-Greeks from an imperial yoke.[2]

In fact it would seem that his literary sympathies have led Professor Murray astray, when he tells us "that, alas! there was no America to make sure that the right side won."[3] For the Peloponnesian was like the European War, inasmuch as the last round was decided by the intervention of a neutral. (It was Persian gold and Persian shipbuilding timber which decisively loaded the scales against Athens at the end.) But it was unlike the European War inasmuch as there was no "right side." The liberators proved, in fact, to have no positive programme. The necessity for a larger political unit than the city-state remained, and empire was forced by circumstance upon them. In proportion as they were stupider, the ever ruder successors of Athens made each a more conspicuous failure than the last. Nor was Dionysios in Sicily in the fourth century B.C. more successful than Sparta and Thebes in Greece.

In fact the Greeks discovered the true principle of the state, but failed to embody it in a political unit of adequate scale. Greek history after the Persian Wars is a catalogue of their failures in practice, while Aristotle betrays the degree of their failure in theory, when he preserves the ideal of political society only by mapping the world into a series of self-centred, isolated city-communities.

There are many points of similarity between the Peloponnesian and the European Wars. How similar were the conditions of life in Athens and in London may be read in the lecture of Professor Murray to which I have referred. The Athenian, like ourselves, knew what it was to be short of food, fuel, and light. Pestilence, like influenza, claimed even more victims than the battle-fields. Beside our modern mediums may be placed the oracle-mongers, whom Aristophanes so cordially disliked, and as regards secular credulity the legend of the landing in England of a large contingent in 1914 is paralleled by the fantastic hopes entertained

[1] In 431 B.C., the first year of the war of the Peloponnesians against Athens.

[2] Thucydides, II, 8.

[3] Creighton Lecture, 1918, *Aristophanes and the War Party* (Allen & Unwin, 1s. net), p. 9.

by Athenians of their Thracian allies. Labour, both domestic and skilled, with them as with us, though for different reasons, became difficult to handle. These and other similarities lead up to the main theme of the lecture, an exceedingly interesting study of the effect of a world-war then and now upon the psychology of politics.

Of the soundness of the parallel in essentials the reader of the lecture will be able to judge. There is in passing a small but curious coincidence which Professor Murray has omitted. Even ruthless sea warfare is a novelty only in its instrument. In this struggle between a maritime empire and a military state, the weaker naval power declared ruthless war upon all sea-borne commerce. Precisely in the same way twenty-three centuries earlier "the Lacedæmonians killed as enemies all whom they took at sea; whether confederates of the Athenians or neutral."[1] The policy was ineffectual, for Sparta was weak above water and lacked the furtive weapon of the submarine. And in ancient as in modern times it had diplomatic disadvantages. We read of representations made to a Spartan admiral that it is a bad way of setting the Greeks at liberty to kill men who have not been guilty of hostile action, and who are not enemies to the Peloponnesians, but confederates to the Athenians by constraint; and that, unless he gave up that course, he would make few of his enemies friends, but turn many now friends into enemies.[2]

The Peloponnesian War differed from the wars of national expansion, or the wars of independence against a foreign invader, in being a war of long duration in which all parties fought to the pitch of exhaustion. In the course of the struggle every Greek state of importance became involved, and from the Greek point of view it was a world-war. Its conclusion left Athens humbled, and her empire shorn away, Sparta, with her domestic institutions strained to the point of revolution, faced with a task abroad with which she was wholly unable to cope, and the rest of the Greek world, like Europe to-day, worn out.

Professor Murray's lecture suggests the possibility of a sequel. While history does not repeat herself with the exactitude in which Thucydides believed, her similarities are not uninstructive. In Athens, as in this country, war-expenditure, depleted resources, inflated currency, and high prices lent a grave importance to financial questions.

The art of the statesman in the fourth century becomes largely the art of making ends meet. Then, as now, there were those who believed that nationalisation provided a panacea for national financial difficulties, and Xenophon's treatise upon *Ways and Means* is largely a plea for the working by the state of the silver-mines, which, though the property of the state, were leased for a premium and rent to the private prospector or industrialist. The financial reserves of Athens, which Pericles had stored in the Parthenon, had in the course of the war been coined and put into circulation. Inflated currency had assisted the scarcity of necessaries in raising prices. The purchasing power of money in the age of Demosthenes was five times less than in the age of Solon.[1] Increase in the cost of living had led to an increase in the amount of state payment for public service, a vicious circle with which we are familiar enough.

Individuals of the middle class were in many cases in financial straits. The landowner and the agricultural middle class had been ruined by the Spartan invasions of Attica. Devastated farms glutted the market, and prudent capitalists like Ischomachus and his father found land a cheap investment. Large estates worked industrially by slave-labour thus supplanted the yeoman's holding. Individuals, again, who had held property in the empire came back to Athens, having lost their possessions. We hear of persons, previously affluent, who are taught by misfortune that working for a living is no disgrace, and Socrates solves the difficulties of a friend, who has a large number of female relations dependent upon him, by suggesting that they should be set spinning and weaving for the market. Capitalism increases, but wealth had passed to a new class. Munition makers almost alone had come out of the war with profit. The fourth century sees the rise of bankers, an ex-slave like Pasion, and the typically spendthrift son of the parvenu like Apollodorus.[2]

Athens maintained her relative importance in the Greek world partly because she became, in a sense other than that intended by Pericles, "the school of Hellas," but mainly because of the sea-borne traffic which inevitably flowed to her great harbour the Peiræus as the central port of Greece. If her condition was bad, that of the rest of the Greek world was worse. Disorder ruled upon land and sea. The land was full of broken men, bandits and desperadoes, while the fall of Athenian power had filled the sea with pirates. Peace was impossible, and the recurring combinations against the paramount power of the day

[1] Thucydides, II, 67, 4.

[2] Thucydides, III, 32.

[1] Boeckh, *Public Economy of Athens* (translated by Lewis), p. 6. Prices were of course rising throughout the period. The spoils of the Persian War enormously increased the amount of coin in circulation. But the rate of inflation increased with war-expenditure, and prices went up with a bound. The depreciation of the value of money continued through the fourth century, in the course of which the Phokians put the treasures of Delphi into circulation. The value of money, particularly of gold, reached its lowest when the conquests of Alexander flooded the money market with the immense reserves of the Persian Empire.

[2] The general reader will find further information in a most attractive form in Glover's *From Pericles to Philip* (Methuen, 1917).

led to a series of fruitless wars enfeebling still further the already exhausted Greek states. The power which Persia showed in 387 B.C. to dictate the settlement of Greek domestic quarrels corresponds to the real facts of the situation. The Greek world had bled itself to exhaustion.

There were not wanting minds which felt that the necessity for Hellenism was union in the place of discord. Professor Murray has pointed out how a revulsion from the experienced horrors of a world war had created dreams of an ideal city where even men have wings.[1] And a more practicable ideal belongs to the same movement of thought. Even during the war, from the publication of the *Peace*[2] onwards, the idea that men should become "good Hellenes" is markedly in Aristophanes' mind. The disintegration resulting from the conclusion of the great conflict loosened local ties, and thereby not only contributed to the marked growth of individualism in the fourth century, but also strengthened the common bond of Hellenism. As a definite political programme, the prototype of the League of Nations finds its spokesman in the Athenian orator Isocrates, who is interesting precisely because he is not a great original thinker, but the mouthpiece of a considerable body of sensible opinion. The discord, jealousy, and rivalry of a narrower patriotism however prevailed. A free and voluntary League of Hellenes never came into being. It was left to the Macedonian Philip and his son, Alexander the Great, to enforce order in the Greek world before conquering Persia and the East. It is to be hoped that the League of Nations will be more exactly realised than were the original aspirations of Isocrates, and that the goodwill of sensible European opinion will find some really effective expression. If not, it would appear that the parallel between the Greek and European worlds in war-time may be extended to the subsequent periods. To students of the history of Greece in the fourth century this is no attractive prospect.

[1] Murray, op. cit., pp. 10, 11.

[2] Aristophanes put his comedy, the *Peace*, upon the stage in 421 B.C.

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The Number of the Elements

By C. G. Darwin, M.C., M.A.

Fellow of Christ's College, Cambridge

THE main endeavour of pure science is to proceed from the study of particular cases to the general laws underlying them. In this respect it is not very surprising to find that chemistry is far behind physics, for chemistry studies the differences between different kinds of matter, whereas physics looks for the unifying principles which underlie them all. In fact, it is hardly too much to say that, as soon as any important generalisation is made in chemistry, the subject of it is promoted (or degraded—according to the reader's taste) to the rank of physics. Thus the beautiful theory developed by the application of thermodynamics to chemistry is dignified with the name Physical Chemistry. The present article deals with another invasion of physics into the chemical domain, an investigation of the fundamental qualities which serve to distinguish between the chemical elements.

In chemical theory a very important part is played by the "Periodic Law." It would take too long to discuss this law fully, nor is it needed for our purpose. Its main point is this: If all known elements are arranged in order of their atomic weights,[2] it is found that certain chemical properties recur at definite intervals. Thus lithium and sodium are both of the group called alkali elements, and are 8 apart, similarly oxygen and sulphur, another pair of closely related elements. For the lower atomic weights the cycle goes by eights, but after two complete cycles it changes and goes by eighteens. In three cases—argon and potassium, cobalt and nickel, tellurium and iodine—it is necessary to invert the order of atomic weights to fit in with the chemical characters. The resemblances of corresponding elements are sometimes not very marked, but they are enough so to prove that there must be some underlying principle, and to enable the chemist to predict the existence of elements through the presence of a gap in the table. Indeed, three of the rarer elements were foretold in this way before their discovery. There still remain two gaps in the table, where there appear to be places for elements that no one has ever found. They ought to be homologous—that is to say, generally similar—to manganese. In the table it will also be seen that there is a curious inter-

[1] A good account of the development of the Periodic Law will be found in the *Encycl. Brit.* under the heading "Elements."

[2] The atomic weight is the weight of an atom of the substance measured on such a scale that the weight of hydrogen is 1. In practice, for technical reasons, it is more usual to take that of oxygen as 16, which is almost exactly the same thing.

THE PERIODIC TABLE

O	I	II	III	IV	V	VI	VII	VIII		
							Hydrogen 1 H 1·008			
Helium 2 He 3·99	Lithium 3 Li 6·94	Beryllium 4 Be 9·1	Boron 5 B 11·00	Carbon 6 C 12·00	Nitrogen 7 N 14·01	Oxygen 8 O 16·00	Fluorine 9 F 19·0			
Neon 10 Ne 20·2	Sodium 11 Na 23·00	Magnesium 12 Mg 24·32	Aluminium 13 Al 27·1	Silicon 14 Si 28·3	Phosphorus 15 P 31·0	Sulphur 16 S 32·07	Chlorine 17 Cl 35·46			
Argon 18 A 39·9	Potassium 19 K 39·1	Calcium 20 Ca 40·1	Scandium 21 Sc 44·1	Titanium 22 Ti 48·1	Vanadium 23 V 51·0	Chromium 24 Cr 52·0	Manganese 25 Mn 54·9	Iron 26 Fe 55·9	Cobalt 27 Co 59·0	Nickel 28 Ni 58·7
	Copper 29 Cu 63·6	Zinc 30 Zn 65·4	Gallium 31 Ga 69·9	Germanium 32 Ge 72·5	Arsenic 33 As 75·0	Selenium 34 Se 79·2	Bromine 35 Br 79·9			
Krypton 36 Kr 82·9	Rubidium 37 Rb 85·4	Strontium 38 Sr 87·6	Yttrium 39 Y 88·7	Zirconium 40 Zr 90·6	Niobium 41 Nb 93·5	Molybdenum 42 Mo 96·0	43	Ruthenium 44 Ru 101·7	Rhodium 45 Rh 102·9	Palladium 46 Pd 106·7
	Silver 47 Ag 107·9	Cadmium 48 Cd 112·4	Indium 49 In 114·8	Tin 50 Sn 118·7	Antimony 51 Sb 120·2	Tellurium 52 Te 127·5	Iodine 53 I 126·9			
Xenon 54 Xe 130·2	Caesium 55 Cs 132·8	Barium 56 Ba 137·4	Lanthanum 57 La 139·0	Cerium 58 Ce 140·2	Praseo-dymium 59 Pr 140·9	Neodymium 60 Nd 144·3	61			
	Samarium 62 Sa 150·4	Europium 63 Eu 152·0	Gadolinium 64 Gd 157·3	Terbium 65 Tb 159·2	Dysprosium 66 Ds 162·5	Holmium 67 Ho ?	Erbium 68 Er 167·7			
	Thulium 69 Tm 168·5	Ytterbium 70 Yb 173·5	Lutecium 71 Lu 175·0	Keltium 72 Kt ?	Tantalum 73 Ta 181·5	Tungsten 74 W 184·0	75	Osmium 76 Os 190·9	Iridium 77 Ir 193·1	Platinum 78 Pt 195·2
	Gold 79 Au 197·2	Mercury 80 Hg 200·6	Thallium 81 Tl 204·0	Lead 82 Pb 207·2	Bismuth 83 Bi 208·0	Polonium 84	85			
Ra. Emanation 86	87	Radium 88 Ra 226·0	Actinium 89	Thorium 90 Th 232·4	Uranium X_2 91	Uranium 92 U 238·2				

For convenience in printing, the part of the table periodic in 18 has been brought into a reduced number of columns. The Roman figure at the head is the number of the group in which the elements vertically below it are classed. The table is read as follows :—Helium, atomic number 2, chemical symbol He, atomic weight 3·99. Where the element is unknown its number is printed large. Among the radio-active elements, only one of several "isotopic" substances has been put in the list. ("Isotopes" are defined later.) Most of the atomic weights of these substances have not been measured. The "rare earths" have no correspondence in properties with the other elements of the columns under which they happen to fall. The three cases where the order of atomic weight must be inverted are A and K, Co and Ni, Te and I.

lude, which is filled by the elements known as the "rare earths." More than a dozen of these are known to chemists, almost all very rare, and so alike that it is only with the greatest difficulty and patience that they can be separated from one another. After this interlude the periodic system returns and continues to the end of the list. Owing to the complete breach with the periodic law, the chemist cannot say whether there are any elements among the rare earths still to be discovered. The physical experiments which I am going to describe prove conclusively that between hydrogen and uranium there are 5 undiscovered elements—the two of the manganese group, one rare earth, and two more among the radio-active elements which come at the end of the list. These results follow from experiments which go much further into the fundamental nature of atoms than is ever done in chemistry. All trace of periodicity or chemical peculiarity disappears, and is replaced by a perfectly orderly progression of properties from which we can argue with absolute confidence.

In examining the atomic weights in the table, it will be observed that (especially near the beginning) the majority of them are almost exactly whole numbers. A great deal of speculation has been built up on this subject in the face of considerable difficulty, because a few, especially chlorine at 35·46, resolutely refuse to conform to the rule. Obviously, but for these exceptions, it would have been reasonable to suppose that all atoms were built up out of hydrogen atoms. Some work done only two months ago has entirely revolutionised this question, and in view of its interest and novelty, it will not be out of place to discuss it here, the more so as it has a considerable bearing on the theory of the fundamental nature of matter.

The electrical theory of matter was developed by J. J. Thomson and his school about twenty years ago. Thomson showed that all atoms contain a common substance—the electron, a particle with a perfectly definite and constant charge of negative electricity, and of mass about one eighteen-hundredth of a hydrogen atom. The question then arises, How many electrons are there in an atom? From their mass we can only say less than 1,800 (in the case of an atom of hydrogen), and to get a more definite value we must adopt some other line of attack. Now an atom is an exceedingly impenetrable body, and any ordinary experiment, say of a chemical or of an optical kind, really touches its surface only. In order to find out

what is inside the atom, very much stronger measures must be taken, and these the discovery of X-rays and radio-activity placed in the hands of the physicist.

When a beam of X-rays traverses matter, a certain amount is scattered in much the same way that the air scatters sunlight and causes the sky to be blue. The amount scattered can be used to get an estimate of the number of scattering centres, the electrons, in much the same way that the brightness of the sky shows how the upper air is constituted. The first estimate of the number of electrons in an atom was derived in this way, and the result came out, though only rather roughly, to be about the same as the value of the atomic weight itself; at any rate, it could not be supposed that any appreciable part of the weight of an atom was contributed by its electrons.

Turning to radio-activity, the evidence becomes far more definite. Radio-activity consists in a succession of transformations of a substance through a perfectly definite series of states. Each state has all the properties associated by the chemist with the word "element," and it is only in the fact of their transmutability that the radio-active elements differ from the others. In the act of transformation each atom throws off a high-speed particle. The particle is characteristic of the element that is changing, and there are two different kinds, known as α- and β-particles. The α-particle is simply a helium atom carrying a positive electric charge equal to twice that of an electron. Its speed depends on the radio-element undergoing transformation, and in the case of the element known as Radium C has the enormous value of one-fifteenth of the velocity of light. The β-particle, on the other hand, is an electron, and its velocity is sometimes almost equal to the velocity of light itself. The speed of both types is so great that they can disregard entirely the impenetrable character of the atom, and go right through it. In doing so they will sometimes go very close indeed to one of the electrons in the atom, and will be deflected from their course by it. The β-particle will be easily deflected on account of its lightness, and indeed it is observed that, if a parallel beam of β-rays falls on a thin sheet of a substance, the emerging beam is scattered so that it is spread over a broad angle. Not so the α-particles. These are so massive, compared to the electrons, that they go right through everything practically in a straight line, and it requires the cumulative effect of a large number of electrons to produce a perceptible spreading of the beam. Experiments were therefore carried out in Rutherford's laboratory in Manchester to estimate the amount of this scattering. The results showed that for the substances examined the number of electrons in an atom was equal to about half its atomic weight.

In the course of the scattering experiments it was observed that a few of the α-particles underwent large deflections, much as do β-particles, and this observation furnished the key to the final solution of the problem. For an α-particle is so heavy that it requires the development of enormous forces to throw it off its line of motion, and these forces can only be caused by another body of large mass and charge. On these grounds Rutherford put forward his theory of atomic structure, which is now universally accepted. An atom has a nucleus of very small dimensions which carries practically the whole of its mass, and has a charge of positive electricity equal to some multiple of the charge of an electron. This charge is neutralised by a cloud of electrons surrounding it, and the number in this cloud, or (which is the same thing) the number of elementary charges in the nucleus, is the fundamental character which determines the chemical nature of the atom. Radio-active transformation is due to a change of the nucleus, and as some transformations give β-particles (which are electrons), the nucleus certainly contains electrons in itself; but these are merged in its total charge, and are not to be counted in estimating the number of electrons in the atom. Chemical processes are only strong enough to scrape off an electron or two, or to make some of the outer ones vibrate, and it requires X-rays or α- or β-particles to get inside and show the qualities of the nucleus and the inner electrons. The laws of the forces ruling in the atom, and still more in the nucleus, are almost completely unknown at present, and constitute one of the most important and difficult problems of physics.

To test Rutherford's theory, very intense radio-active sources were prepared so that considerable numbers of α-particles would be deflected to broad angles, and these numbers were counted. The results bore out the theory completely, and indicated nuclei of strength equal to a half or a little less than half of the atomic weight. This was found for gold, platinum, tin, silver, copper, aluminium, and carbon. An eighth case can be at once added, the α-particle itself. In the course of its violent history it is certain that any electron attached to it would be scraped off. In other words, it is itself the nucleus of the helium atom, and its charge, 2, is half its atomic weight, 4.

Now if the elements are numbered off, starting with hydrogen as 1, and going in order of their atomic weights, it will be observed that the resulting numbers are all (excepting hydrogen itself) half the atomic weight or a little less. So there is a very strong suggestion that it is this number that is really being given by the experiments. If the α-particle experiment were susceptible of a high degree of accuracy, we should have a perfectly direct way of counting what the exact number is in each case, and could in this way also discover any gaps in the series. But to get even rough

results is very difficult, and fortunately, when the problem had reached this stage, a less direct but much more powerful method had been developed, which in the course of a very short time finished it off.

The experiments of Laue and his collaborators proved that X-rays were a type of light,[1] and the Braggs discovered that there was a characteristic spectrum emitted by the substance of the target of their X-ray tube. Moseley[2] developed an exceedingly powerful method of finding the characteristic spectrum of any substance, and in the course of a few months examined the majority of the elements. Whereas the visual spectrum of a substance depends on its place in the periodic table (for example, the spectra of lithium, sodium, and potassium all show a strong family resemblance), in the X-ray spectrum no periodicity is shown, and instead there is a perfectly orderly progression from element to element along the list. The structure of all the spectra is exactly the same, and the only difference is that each in succession has all the wave-lengths of its lines reduced in a definite proportion. Moseley's work extended throughout the region between aluminium and gold, and it has since been extended up to uranium. More remarkable still is the fact that, if the system is carried back to the beginning of the list, where no X-rays can be found at all, the spectrum corresponds to the ordinary visual spectrum of hydrogen.

Now here we have an absolutely certain way of counting elements, and Moseley of course took advantage of it. He at once showed that cobalt should come before nickel (this the less direct X-ray methods of Barkla had done already), and a little later that potassium comes next to calcium (argon, being gaseous, could not be tested), and that tellurium comes before iodine. He also confirmed the two "manganese" gaps predicted from the periodic table. He then turned his attention to the rare earths, and found that they do not differ from other elements in the least, but show the same orderly progression. His study revealed the extraordinary difficulties which face the rare-earth chemist. Salts of a rare earth warranted pure would be found to contain 80 per cent. of other rare earths. He examined all the specimens he could collect, and found 14 elements between lanthanum and tantalum, with one gap. Now it happened that at this very time Urbain, the most famous living specialist in this subject, himself the discoverer of several of the rare earths, thought that he had isolated a new one. Moseley's method provided an instant test, and Urbain therefore brought his specimen to Oxford to be examined. It was found to consist of a mixture of three known elements with no trace of the missing one.

Thus the outcome of Moseley's work is that there are definitely three and no more unknown elements between aluminium and gold. Two are somewhat like manganese, and would have atomic weights about 100 and 190. The third is a rare earth with atomic weight about 148. Below aluminium X-ray methods are inapplicable, but from the absolute regularity of the periodic table in this region, and above all from the correspondence of the X-ray spectra with the visual spectrum of hydrogen, there can be no gaps there. Thus we can with certainty number the elements, starting with hydrogen at 1 and ending with uranium at 92. There are five missing numbers—43, 61, 75, and in addition two more, 85 and 87; but the last are in the radio-active region, and we must turn to another type of evidence.

We have seen that radio-activity consists in a substance transmuting itself through a succession of states, each of which is a chemical element. The sequences are now well known, and all told something like forty transformations have been found. They all originate from either uranium or thorium, and there has long been very little doubt that they end their radio-active career as lead. The majority are never present in more than infinitesimal amount, but in a few cases they can be isolated and studied by ordinary chemical methods. Thus radium itself resembles barium, and so is naturally assigned a place under it in the periodic table. In spite of their resemblance, the separation of radium from barium is quite an easy process, but this is not so in the case of all radio-elements. Thus there is a substance called Radium D which is present in considerable quantity in uranium ores. It is always separated from the ores along with the lead. As it would be useful to have it as a radio-active source for some purposes, much effort has been expended in trying to purify it from the lead, but always without success. There are many other cases where substances, undoubtedly different from their radio-active behaviour, once mixed together cannot be separated or distinguished chemically or even spectroscopically.

Now consider how this fits in with our ideas of atomic number. We know of 43 different radio-active elements, but there are only 9 numbers available for them, those from 92 to 84. To reconcile these facts, the hypothesis of "isotopes" was put forward.[1] Isotopes are substances of different radio-active behaviour, but with the same chemical characters, and the hypothesis asserts that such will be quite inseparable by any chemical means. It will be seen that this fits in per-

[1] See any modern book on X-rays, for example W. H. and W. L. Bragg, *X-rays and Crystal Structure*.

[2] H. G. J. Moseley worked in Manchester and afterwards at Oxford. He was killed during the Suvla Bay landing at Gallipoli, serving as Signals Officer to an infantry brigade, an immense loss to science.

[1] Simultaneously by A. S. Russell, F. Soddy, and K. Fajans. The word "isotope" is due to Soddy, and implies the "same position" in the periodic table.

fectly with the idea of atomic number, and it is now perfectly straightforward to see how the number will change in a transformation. For the emission of an α-particle involves a loss of 2, and so the atomic number will be reduced by 2 when it is thrown off. Similarly, a β-particle transformation will increase the number by 1, as here the particle is a *negatively* charged electron. If this principle is applied the whole system of radio-elements is cleared up, and a complicated chain can be worked out, starting with uranium at 92, and ending with lead at 82, some steps decreasing by 2 and others increasing by 1. A similar chain starts from thorium at 90, and also ends with lead. If these chains are examined, it will be found that most places are filled several times over, but that none of the elements fall into the places 85 and 87. These are the two other missing elements.

We next push the principle of isotopes a little further. If the weights of all the particles it emits during transformation are subtracted from the weight of a uranium atom, the result should give the weight of the end-product. There are 8 α-particles (the β-particles are insignificant in weight), and so the result should be $238{\cdot}2 - 8 \times 4 = 206{\cdot}2$. Now the end-product is lead, and its atomic weight is usually accepted as 207·1. This suggested determining the atomic weight of lead derived from radio-active ores, as presumably this lead would be partly composed of extinct radio-active matter, and the value found was 206·4, quite different from ordinary lead. This was the first definite attack on the chemist's faith in atomic weights. This faith has been shattered by the experiments now to be described.

It has long been known that, if an electric discharge goes through a vacuum tube (such a tube always contains a little gas), charged atoms are produced moving at high speeds, and so able to affect a photographic plate. These are called positive rays, from the sign of the charge they carry.[1] By means of electric and magnetic fields they can be deflected, and from the amount of deflection their weights can be found. Working on these lines, Thomson examined the atomic weights of many of the elements. In most cases the result fully confirmed ordinary chemical evidence, but in neon (atomic weight 20·2) it was consistently found that there was a faint line on the photographs corresponding to 22, as well as the line at 20. There was thus a strong suggestion that neon is composed of two isotopes, nine-tenths having an atomic weight of 20, and one-tenth an atomic weight of 22. Now isotopes cannot be separated by ordinary chemical means, yet any gases whatever can be separated by the physical process of diffusion if their weights are different. Aston therefore set to work to try and separate out a heavier type of neon. The method is very tedious, even when made self-acting, as many million operations are needed. After a long succession of trials he obtained faint indication of improvement, but not enough to encourage him to proceed. He therefore turned his attention again to positive rays, and with a greatly improved apparatus was able to prove that neon is certainly double, part exactly at 20 and part exactly at 22. Turning to other substances, chlorine seemed of special interest, as its atomic weight, 35·46, is nowhere near a whole number. He at once found that it is double, three-quarters at 35 exact, and one-quarter at 37 exact. In the same sense mercury was also found to be composite. These results are not two months old, and there the matter rests for the present.

It is impossible to see how far Aston's results will go, but a little speculation is irresistible. It looks as if we were going to find that all atomic weights are whole numbers after all. This is simply a new form of a very old idea, a forerunner of the periodic law, famous as "Prout's Hypothesis." The only difference is the important one that now an element may have more than one atomic weight. In terms of Rutherford's theory, this means that nuclei of the same total charge can be built up in different ways exclusively out of hydrogen atoms and electrons. For example, chlorine has number 17 and weight 35 or 37; so its nucleus is composed either of 35 hydrogen atoms cemented together by 18 electrons, or 37 hydrogen atoms and 20 electrons. When the corresponding facts have been explored for the other elements, they may perhaps throw a dim light on to the future problem of the structure of the nucleus.

Summarising our results, we have shown how the periodic law of the chemist has been replaced—it still remains to explain it—by the conception of atomic number—that is, the number of elementary charges of positive electricity concentrated on the nucleus of the atom. We have seen that, of the 92 elements from hydrogen to uranium, all are known except five, Nos. 43, 61, 75, 85, and 87. Looking back to the periodic table, we can say that 43 and 75 would bear a family resemblance to manganese, 61 would be a rare earth, 85 a halogen (i.e. one of the chlorine group), and 87 an alkali-metal. From another point of view we have seen that atomic weight is only loosely connected with atomic number, and it looks as though all nuclei were built up of hydrogen atoms and electrons exclusively. There is thus a curious inversion of the interests of chemist and physicist. The reverence of the chemist for atomic weight must cease, and in future he must venerate atomic number only. On the other hand, an exact knowledge of atomic weights will be one of the few guides the physicist will have in his investigation of the structure of the atomic nucleus, the main foundation of all matter.

[1] An account of this subject will be found in Sir J. J. Thomson's *Positive Rays*.

England's "Peaceful Penetration" of Germany in the Middle Ages

By L. A. Willoughby, Ph.D., D.Lit.

Lecturer in German in the University of Sheffield

It has long been a matter of controversy with scholars to what extent German language and literature in the eighth and ninth centuries were indebted to Anglo-Saxon influence. A most important contribution to the subject, invaluable to the historian and the linguist alike, was published recently.[1] The essay is from the pen of the veteran "Germanist" Wilhelm Braune of Heidelberg, who with Hermann Paul, Eduard Sievers, and Friedrich Kluge, form a stalwart band of *Junggrammatiker* (alas! no longer young), a term used to distinguish them from the older school of Grimm and Lachmann and the great pioneers of last century. A life-long student of Old High German Language and Literature, he is famous in the modern language schools throughout the Old and New World as the author of the standard Grammar and Dictionary of Old High German. These have made him the greatest living authority on the oldest periods of German, and it is only fit and proper that he should be the author of one of the most interesting philological discoveries of modern times.

It is well known that the conversion of Germany was undertaken by a native of Devonshire, the Anglo-Saxon Wynfrith, famous in the annals of the Church as St. Boniface. In A.D. 719 he was commissioned by Pope Gregory II to the heathen nations of Germany, and laboured unceasingly as a missionary for thirty years. The founder of cathedrals and bishoprics, Archbishop and Primate of all Germany, Wynfrith resigned dignities and honours that he might devote himself the more effectively to his great mission. In 754, whilst holding an open-air confirmation service in Friesland, the "Apostle of Germany" won the martyr's crown. His remains were eventually brought back to Germany, and buried in the celebrated monastery of Fulda, which he himself had founded.

The Anglo-Saxon mission in Germany, however, began even earlier. Its extreme limits date from the landing of Wilfrid in Friesland in 678 to the installation of Willehad as Bishop of Bremen in 787.[2] The anxiety of the English for their German brethren may be explained very largely to the fact that they still considered the latter (or at least the Saxons) to be of the same stock as themselves. Boniface, in urging his countrymen to undertake missionary work among the Germans, reminds them that they are people "of their own flesh and blood," and in the eighth century the Saxons in Germany were known in England as "Altsaxones."

The English mission reached its height with the intense activity of Wynfrith in Middle Germany. English priests came over, not in dozens, but literally in hundreds, and of the newly instituted benefices in Thuringia, Hesse, and East Franconia, most were held by Englishmen.

But their activity extended also to the South, and a great religious revival was instituted by Boniface in Bavaria under the auspices of Duke Odilo, with the result that many English monks were inmates of Bavarian and Alemanic monasteries. It is no wonder, therefore, that this great influx of Anglo-Saxon priests, with their superior "Kultur," should have influenced the intellectual life of the Germans in all directions. It made itself evident at once in the introduction of the Anglo-Irish Script, which maintained itself until the ninth century. It was naturally not to be expected that the monks would further the national heathen literature, but that the religious literature of Germany, and especially Old Saxon poetry, was largely written under Anglo-Saxon inspiration is now an accepted fact. To what extent Old High German literature itself stands indebted to Anglo-Saxon poetry is still a moot question; the most extravagant claims have been made, but without meeting with general acceptance. But part, at least, of the *Vocabularius St. Galli*, the famous dictionary of the monastery St. Galli in Switzerland, dating from the middle of the eighth century, can be proved to have been based on an Anglo-Saxon model, whilst the *Baseler Recepte* show an admixture of Anglo-Saxon forms. Even the vocabulary of the Old High German translation of Tatian's Harmony of the Gospels contains no fewer than two hundred and eighty words which do not occur in other High German Sources, but are peculiar to Anglo-Saxon or Low German districts.[1]

Thus whilst the certain examples of the influence of Anglo-Saxon on literary German are restricted to a few solitary instances, yet Anglo-Saxon phraseology certainly influenced most powerfully the living spoken language. The English missionaries, in their efforts to expound the new doctrines, had to coin many new words and expressions (when they naturally turned to such terms as were familiar to them in their own tongue), or place a fresh interpretation upon the old. Now there existed already before the advent of Wynfrith an older stratum

[1] *Beiträge zur Geschichte d. deut. Sprache u. Literatur*, 1918, vol. xxiii, pp. 361 et seq.

[2] See *Kirchengeschichte Deutschlands*, vol. i, pp. 448–594, by A. Hauck; also *Deutschland und England in ihren kirchlichen Beziehungen*, by the same author.

[1] This translation was written in the monastery founded by Wynfrith at Fulda.

of Christianity, due to Latin, i.e. Roman, influence between the fifth and the seventh centuries. It was naturally to be found in those parts of Germany which had formerly been under the sway of Rome—i.e. in the South, and in the Rhine districts. But cut off as they were (in the South at least) from Christian intercourse, and encompassed all about with heathen tribes, these Christians had fallen sadly away from the pure faith, and their belief teemed with errors and superstitions. Yet Christianity had flourished long enough in these regions to give rise to a new terminology, which had thus been in existence for some hundreds of years when the Anglo-Saxon missionaries entered the country.

We notice, then, in many cases a duel between two expressions, the one German, the other English. Thus the English found the Latin loan-word *kruzi* (crux, crucis) already so firmly established that their *ród* (rood) could make no headway. So, too, the High German *opfaron* (Mod. German *opfern*), borrowed, as the operation of Grimm's Law shows, at an early period from the Latin *operari*, held its own against the interloping Anglo-Saxon *offrian* (from the Latin *offerre*), of which only a few instances occur in Old High German; the O.E. *gotspell* (gospel) competed for a time with the Latin *evangelio*, but the latter won the day. In the above-mentioned Tatian translation we find the word *sibba* with the Anglo-Saxon meaning of "peace," instead of the usual sense of relationship which it has preserved in Modern German; nor could the adjective *ôdmustig* (O.E. *éaðmód*), which occurs quite commonly in the Rhine-Franconian author Otfrid, displace the Upper-German *desmuoti*, which has subsisted in the Modern German *demutig*.

Occasionally, however, and in some very important and interesting examples, the Anglo-Saxon word completely supersedes the German expression. Thus there were two Germanic words corresponding in meaning to the Latin *sanctus*, both occurring in Gothic as *weihs* and *hailags*. In England the form *wéoh*, with its cognate word *wíʒ* (idol), was apparently obnoxious to churchmen on account of its connection with the heathen cult.

And so the Latin *sanctus* was, in an ecclesiastical sense, translated by *háliʒ*, and the adjective corresponding to *wíʒ* was quietly dropped. In Old High German, on the other hand, the term *wîh* had obtained almost complete mastery over *heilac*, which was only used in the old meaning of inviolate, intact. The common ecclesiastical phrase was *wîh*, as we know from the earliest glosses for *sanctus*. In a short time, however, under the influence of the English mission, the O.E. *háliʒ* completely ousted *wîh*, so that even as early writings as those of Tatian show no trace of it. It has only survived in Modern German in a few formal expressions like *Weihnachten* (*zen wîhen nahten:* at the holy nights), in *Weihrauch* (sacred smoke, i.e. incense), and in a few Bavarian place-names like Weihenstephan, Weihenzell.

Similarly the English churchmen translated the Latin *spiritus sanctus* by *háliʒ ʒást*. *ʒást*, German *Geist*, was a word common to all the West German dialects, and seems to have had the primitive meaning of "apparition" (cf. our English *ghost*). It was certainly in this sense that the word existed in High German, for the phrase already adopted by the South German Christians was *wîh atum* (Mod. German, *Atem*). But so thorough was the Anglicising of German ecclesiastical terminology that *der heilige Geist* is still to-day the only designation for the third Person of the Trinity, while *Atem* has ceased to be current with the meaning of "Spirit" since the end of the twelfth century.

Equally, or even more significant, is the fact that the German name for the greatest Christian festival is of undoubted Anglo-Saxon origin. Whereas all the Germanic peoples denote Easter by variants of the loan-word *pascha* (Gothic *paskia*, Middle Low German *pasche*, Middle Dutch *paeschedach*, Old Frisian *pascha*, Old Norse *páskar*, Swedish *pask*, Danish *paaske*), the English and Germans (i.e. the High Germans) alone know the festival as Easter or *Ostern*. The etymology of the word occupied the attention of no less a person than the Venerable Bede, who, in 725, stated that the Eostur-monath was so named after a feast of the heathen goddess Eostrae, which fell near the time of our own Easter.[1] And though this explanation has been scouted by some scholars, yet the fact that similarly Yule (O.E. *ʒéol*) was originally the feast of the winter solstice, and was afterwards Christianised, would seem to support Bede's statement.

We have seen how the English in the train of Boniface were numerous and influential enough to change the very language of their converts for all time, and in some very important respects. But the climax is still to come. The very name by which the Germans speak of themselves to-day, the word *deutsch* as a description of the whole German people, is of English origin. That *deutsch* goes back to an adjectival form *diutisch*, itself derived from *deot* (A.-S. *þéod*), meaning the people in its totality, is an incontrovertible fact. But it is equally certain that the adjective *diutisch* does not occur in German until Notker uses it in the first half of the eleventh century. When Otfrid, in the first half of the ninth century, wished to give expression to the notion of his own German tongue in contrast to Latin, he, being a Franconian, used the expression *frenkisg*. In other words, he had no conception of a German language (or of a German people either for that matter)

[1] See Chapter XV of Beda Venerabilis, *De tempororum ratione; De mensibus Anglorum.*

apart from each tribal dialect. On the other hand, a foreigner like St. Boniface must have been sufficiently conscious of the distinction of his own language from that of his converts, and was in a better position than a native to visualise the people as a separate entity. And there is considerable evidence to show that the learned term *theotiscus*, which in its earliest use is always applied to the language, and on the analogy of which the German *diutisc* was formed, was an invention of the Anglo-Saxon mission, and formed on the model of their own *þeodisc*—i.e. of, or belonging to, the people. At all events the first use of the term occurs in 786 in a Latin document referring to an English synod.

From 788 onwards the Latinised term *theotiscus* is common in Germany in the special sense of applying to the conglomeration of German dialects as a whole in contrast to Latin. It seems quite likely, as Braune suggests, that the first incentive to its use with this particular meaning went out originally from the Anglo-Saxon Wynfrith, who as spiritual head of the German Church had need of a single term to denote the language of his whole people.

Gravitation and Light

By H. Spencer Jones, M.A., F.R.A.S.

Chief Assistant at the Royal Observatory, Greenwich

DURING the past few months, much attention has been given in the Daily Press and elsewhere to what is known as the "Generalised Theory of Relativity." The average person who has endeavoured to follow the discussion which has ensued has doubtless acquired but a very hazy notion of the nature of this theory: he will probably have concluded, however, that so much discussion can only have been caused by a theory which marks a definite epoch in scientific thought. The theory, which has been developed by a Continental physicist, Professor Albert Einstein—whose name is now a household word—does, in fact, revolutionise our conceptions of space and time.

The present article is not concerned with this theory, but with the discovery which attracted general attention to it and started the discussion. This was the proof that the path of a ray of light is bent when it passes near matter. Whether Einstein's theory is true or not—and men of science are divided into two camps on that question—it cannot be denied that this result has been definitely established by recent astronomical observation. Its importance is due to the fact that it is the first new thing which we have been able to learn about gravitation since the master mind of Isaac Newton enunciated the law of gravitation more than two hundred years ago.

Newton's law of gravitation states that any two particles of matter attract one another with a force which is proportional to the product of their masses, and inversely proportional to the square of their distance. Expressed mathematically, if m, m^1 are the masses of the two particles and r their distance apart, the force of attraction between them can be written kmm^1/r^2, where k is a constant called the "constant of gravitation," which is the same for any two particles. Newton showed that this law was satisfied by the motions of the planets round the sun, the laws of which were stated by Kepler, and also that it governed the motion of the moon around the earth. The increasing refinements of astronomical observation have since served to increase our confidence in the law and its universality, and the discovery of the planet Neptune, the story of which is so well known, was a further triumph for the law.

Yet, strange to say, until a few months ago our knowledge of gravitation still stood where Newton left it. Although so universal, and governing every action of our daily life, it has remained aloof from the other forces of Nature. We have gained more or less clear conceptions of what constitutes sound, heat, light, electricity and magnetism, and of the properties of material bodies such as elasticity, cohesion, rigidity, etc., but only now has the barrier of gravitation been broken down.

It is a tribute to the sagacity of Newton that he foresaw the manner in which this barrier might be broken down, for in his *Opticks* we read: "Query 1.—Do not bodies act upon light at a distance, and by their action bend its rays, and is not this action strongest at the least distance?" Newton, of course, believed light to consist of minute corpuscles emitted by a body, and it was therefore to him a logical possibility that the corpuscles might be attracted by matter and fall towards it in a similar manner to that in which the bullet from a rifle falls towards the earth. However, Newton was not in a position to establish his query. That was left for the twentieth century.

We will explain first the observed phenomenon, and then the manner in which it was established.

In Fig. 1, suppose S to represent the sun, E the eye of

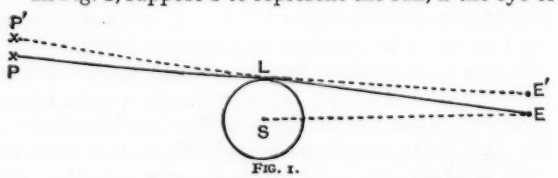


FIG. 1.

an observer on the earth, and P a star which is seen by the observer close to the sun's edge. The figure is not

drawn to scale: if it were, and SE were taken as representing 10 inches, then the diameter of the sun would be $\frac{1}{10}$th inch, and the distance SP, for a near star, would be something like fifty miles. Then the result which has been established is that P, L, E do not lie in a straight line, the rays of light from the star being bent by the gravitational action of the sun, so as to consist practically of two straight portions PL, LE. The rays coming to the observer along the direction LE cause the star to appear at P^1 in EL produced. The ray from the star if it were not bent would come to E^1 instead of E, and the distance EE^1 may be used as a measure of the deflection of the light. On the scale which has been mentioned above, in which SE is 10 inches, the displacement EE^1 would be about the ten-thousandth part of an inch. Expressed otherwise, the angular displacement, which may be measured by either the angle ELE^1 or the angle PLP^1, is 1·75 seconds of arc. A second of arc is the angle which would be subtended at the eye by a halfpenny at a distance of three miles.

These figures apply in the case of a star, the light from which just grazes the edge of the sun. For stars appearing further from the centre of the sun the deflection is less, its magnitude varying inversely with the distance from the sun's centre. Thus, for instance, if the apparent distance of the star from the sun's limb or edge is equal to the sun's radius, the deflection will be 0″·87, i.e. 1″·75 divided by two. If it is at twice this distance from the limb (i.e. at a distance equal to three radii from the centre), the deflection will be 0″·62.

Owing to the great brightness of the sun, it would of course ordinarily be quite impossible to see stars so near the edge of the sun. Moreover, the amount of the deflection anticipated (and predicted by Einstein) is so small that the only body with a large enough mass to use for the purpose is the sun. It would require a precision far exceeding the highest so far attained in laboratory measurements before the effect could be established by means of laboratory experiments. The only remaining possibility is to take advantage of a total eclipse of the sun, when the moon comes between the earth and the sun, blotting out the light from the latter. When a total eclipse occurs, complete darkness does not ensue, as there is then seen around the sun a fringe of bluish-white light called the solar corona (see Plate), which has a brightness somewhat exceeding that of the full moon, and which cannot be seen at any other time. The nature of the corona is not completely understood, as its shape varies considerably from one eclipse to another. It is known, however, to consist of gaseous matter in a state of great rarefaction; the principal element in it has not yet been discovered on our earth, and has therefore been termed coronium.

Even when a solar eclipse occurs, the stars near the sun will not in general be sufficiently bright to be visible to the naked eye, and we must call to our aid the photographic plate. By giving an exposure of sufficient length, the plate will accumulate the light impressions which it receives, and so render even faint stars visible.

Total solar eclipses do not occur very frequently; the last occurred on May 29, 1919, and the next will occur on September 21, 1922. Moreover, they are only visible over a very limited portion of the earth's surface. The apparent diameters of the sun and moon are so nearly equal that the shadow of the moon cast by the sun at an eclipse is in the form of a very elongated cone, whose point or apex is near the earth's surface; the section of this cone by the earth is therefore a region not covering very many square miles. As the moon and earth move relatively to the sun, the shadow traces across the earth's surface a narrow band, and it is only at points on the earth's surface within this band that a total eclipse of the sun is visible.

The total eclipse of May 29, 1919, was a peculiarly good one for the purpose of these observations, as the sun then happened to be in a region of the heavens containing an unusually large number of bright stars. In fact, if the course of the ecliptic—i.e., the apparent path of the sun in the heavens during each year—be traced on a star map, it will be found that no more favourable opportunity could have occurred. It will not occur again for a few hundred years. The eclipse track on this occasion crossed Brazil and the Atlantic Ocean, passed over the Island of Principe, and crossed Africa from Cape Palmas in Liberia to Lake Tanganyika. It was arranged by the Joint Permanent Eclipse Committee of the Royal and Royal Astronomical Societies that two expeditions should be sent out to secure the necessary observations, and in order to reduce the risk of bad weather spoiling the observations, it was decided that one party should proceed to Sobral, in the State of Céara, Brazil, and another to Principe. The conditions in Liberia appeared too unfavourable, although, as events turned out, the conditions there during the eclipse were much superior to those which obtained in Principe. The observations at Principe were spoiled by light cloud, which partially obscured the sun throughout totality; the plates taken were useful, however, as serving to confirm the results obtained by the Sobral observers. At Sobral, the region of the sky around the sun was clear for the greater part of totality, but for the remainder it was veiled by thin cloud.

Two series of photographs were obtained with two different instruments. For the sake of brevity, we will refer only to the better series of the two. A photographic camera was used whose lens had an

aperture of 4 inches, and a focal length of 19 feet. The telescope was not pointed directly to the sun, but was for convenience supported in a fixed horizontal position and fed by an 8-inch coelostat. The latter consists essentially of a plane silvered mirror, which is turned by clockwork about an axis parallel to the axis of the earth's rotation, and at such a rate that the light from the sun is always reflected in the same direction. The photographic plates used measured 10 by 8 inches. The focus of the instrument was carefully adjusted, first by visual observations, and then finally photographically by a series of exposures on a bright star. Eight plates were obtained with this instrument during totality, each having an exposure of 20 seconds. When these plates had been developed, it was found that, with a single exception, they all showed images of seven stars, the remaining plate having been spoiled by cloud. The images were round and sharply defined, and suitable for accurate measurement in a micrometer.

In order definitely to establish the existence of a deflection, it is of the utmost importance that the scale of the photographs should be determined with the highest accuracy possible—i.e., the equivalent value in angular measure of, say, 1 mm. on the plate must be known. To provide material for determining this, the same region of the sky was photographed a few months later with the same instrument, none of the adjustments having been changed in the meanwhile, and the sun by that time having moved sufficiently far from the field for photographs to be obtained in the early morning before sunrise. These photographs were taken when the star-field was at approximately the same height above the horizon as it was during the eclipse: this ensures that the effects of refraction on the positions of the stars are very approximately the same on the two series of plates. An additional photograph of the field was also obtained on another plate through the glass—i.e., the back or non-sensitised side of the plate was turned towards the field—so that on development the star images appeared reversed: if this plate, which we will call the key-plate, and one of the other plates were placed film to film, the corresponding star images were approximately superposed. This considerably simplified the process of measurement, as will now be explained.

The key-plate and one of the other plates were placed films together in a measuring apparatus. The latter consists essentially of a frame for carrying the photographs which can be moved up and down on a slide: the plates are viewed by a microscope which is capable of movement along a slide parallel to the plate, but perpendicular to that just mentioned. Any part of the plate can therefore be brought into the field of view of the microscope, and the two films being in contact, the star images on each are in focus at one and the same time. The distances apart of the two images did not exceed one-third of a millimetre, and this distance was measured for each star by means of a micrometer in the eyepiece. By comparing first an eclipse-plate and then a scale-plate successively with the key-plate, the relative differences in position of the stars between the eclipse- and scale-plate could be at once obtained. For convenience, the components of the differences in two directions were measured, viz. in right ascension and declination. The latter direction is that joining the star to the pole; the former the direction perpendicular to this, or, in other words, the direction in which the star apparently moves, owing to the rotation of the earth. In this way, each eclipse-plate was compared with a corresponding scale-plate, and by a process which need not be elaborated here, but which is not quite so straightforward as it may apparently seem, the effects due to scale and deflection are separated, and the displacement of each star determined.

It is important that the magnitude of the quantity which is being sought should be grasped. One second of arc corresponds to about one-thousandth of an inch on the plates, and the star images themselves are about three seconds of arc in diameter. The greatest calculated displacement for any star on the plate was somewhat less than one second. Yet these quantities are capable of accurate measurement, and, in fact, the plates were measured independently by two different persons, who obtained substantially the same results.

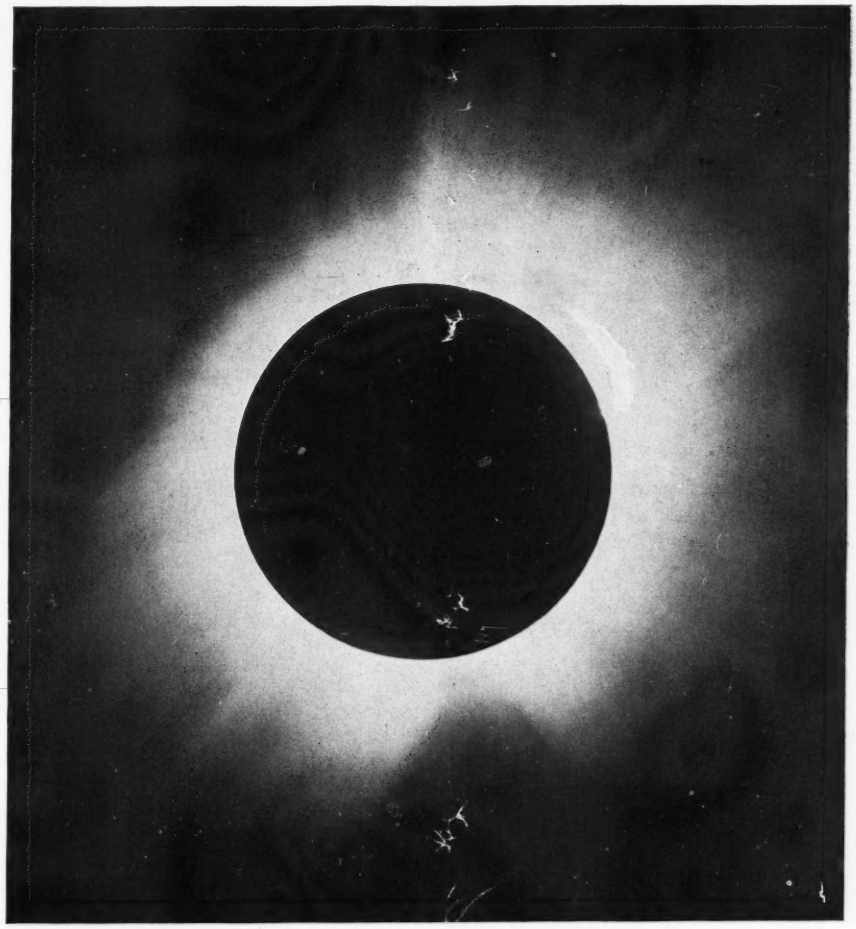
The results may be summarised in the following table:

Star No.	Displacement in Right Ascension.		Displacement in Declination.	
	Observed	Calculated	Observed	Calculated
11	− 0″·19	− 0″·32	+ 0″·16	+ 0″·02
5	− ·29	− ·31	− ·46	− ·43
4	− ·11	− ·10	+ ·83	+ ·74
3	− ·20	− ·12	+ 1·00	+ ·87
6	− ·10	+ ·04	+ ·57	+ ·40
0	− ·08	+ ·09	+ ·35	+ ·32
2	+ ·95	+ ·85	− ·27	− ·09

The first column of this table contains the reference number of each star, and the following columns contain the measured and calculated displacements in the two separate directions. The latter are calculated according to the formula $1''{\cdot}75/r$ where r is the apparent distance of the star from the centre of the sun measured in terms of the sun's radius as a unit.

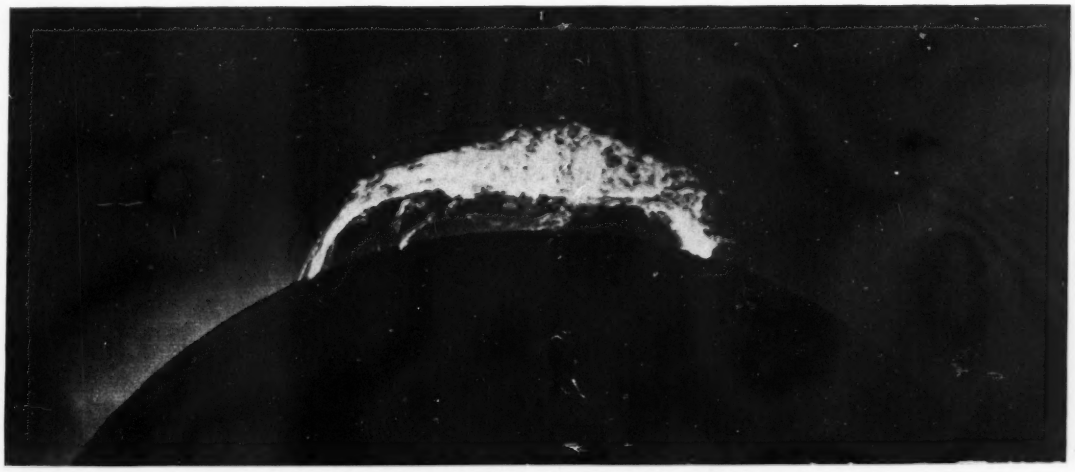
In view of the smallness of the quantities sought for, the agreement is remarkable, the discordances being well within the limits of measurement. The displacement at the limit given by these measures would be 1″·98, somewhat larger than the amount predicted by

PLATE I



SOLAR CORONA: MAY 29, 1919.
(*Photographed at Sobral, Brazil. Exposure* 28 s.)

PLATE II



LARGE SOLAR PROMINENCE: MAY 29, 1919.
(*Photographed at Sobral, Brazil.*)

Einstein, but the excess may be due partially or entirely to a refraction effect by the solar corona.

Astronomers, who are familiar with the errors incidental to the measurement of astronomical photographs, accept the evidence as definitely establishing the existence of the deflection; and their verdict has naturally been accepted by scientists in general. Many attempts have, however, been made to show that the deflection can be attributable to other causes than the sun's gravitation. We have not space to enter into these here, but we may add that, in the opinion of those most competent to judge, these "explanations" are invalid, and for the most part extremely artificial. The present writer believes that the deflection can be attributed only to a direct effect of the sun's gravitational field, and that the answer to Newton's query is therefore "Yes."

Although not the special purpose of the expeditions, it may be mentioned that incidentally some excellent photographs of the solar corona were secured. In the Plate is reproduced one of the photographs taken at Sobral, showing the corona around the obscured disc of the sun. The star images do not show in the reproduction, being too small to appear. The lower photo shows the large prominence which was on the sun's eastern limb at the time of the eclipse. Its mean height is about 120,000 miles, and its length about 380,000 miles. Prominences can, by the use of special apparatus, be observed at times other than eclipses, and this particular one was under observation at the Yerkes Observatory for some time prior to the eclipse. Shortly after the eclipse, the prominence broke up, and within a few hours the greater part of it had rapidly ascended to a height of over 400,000 miles. Prominences consist mainly of incandescent hydrogen gas, and are connected with the disturbances occurring within the sun, which are also evidenced by sun-spots. The exact nature of the physical causes underlying their formation is not known. The prominence of May 29, 1919, was much larger than the average, and never before has so large a prominence been photographed during an eclipse. The splendid photographs obtained of it were a welcome by-product of the eclipse expeditions.

The Cambridge University Press have undertaken to publish a new work, entitled *The Cambridge Ancient History*. This work, of which the general plan will be similar to that of the *Cambridge Modern* and *Mediæval Histories*, will consist of eight volumes, and, beginning with an account of archæological discovery, will trace the history of Egypt and Babylonia, Assyria and Persia, Greece and Rome, to A.D. 324.

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The Stamp Act of 1765

I. The Conditions and Circumstances Preceding the Act

By C. H. K. Marten, M.A.

Assistant Master, Eton College

THE year 1765 is one of the most memorable in the history of the world. It saw the invention of Watt's steam-engine; and it witnessed the passing of the Stamp Act devised by England's chief minister, George Grenville. Watt's invention revolutionised the conditions of industry, and, in consequence of Stephenson's development, the means of communication; Grenville's unfortunate Act was the beginning of the disputes and misunderstandings which led to the foundation of the United States of America. And the Stamp Act still lives. It still helps to poison the relations between Great Britain and America. An English writer, fresh from his impressions of a recent visit in America, says "that the alleged selfishness and injustice of the Mother-Country constitute the history and traditions of America"; and an American, who has recently published a pamphlet on the school text-books used in America, shows that some of them, old themselves and based on obsolete histories, still help to prejudice the rising generation against Great Britain. Many of us remember from our own school-days that we regarded England as the wicked dragon in the story, and America as the innocent fairy. And we comforted ourselves with the reflection that, after all, Grenville was but a pedantic lawyer, and the representative of what we considered to be a corrupt aristocracy, whilst George III was the son of a German mother who had dinned into him German ideas on the omnipotence of kings, ideas which were far removed from those held by most Englishmen at that time.

Of late years, however, the whole story of England's relations with her Colonies has been reinvestigated. And it is a happy example of the impartiality of historians that the inquirers, both in England and America, seem to be unaffected by their nationality. Indeed, it is not a little curious that the most convinced believer in England's wrong-headedness, amongst recent writers on the American Revolution, should be an Englishman, Sir George Trevelyan; whilst for more tolerant views of the policy pursued by the Mother-Country we must go to American historians such as Mr. G. L. Beer or Mr. O. M. Dickerson.[1] The present article agrees with the more tolerant writers. England may have been injudicious and bungling in her policy; she certainly had no intention to be unjust. And the circumstances at the time of the Stamp Act were so difficult that it is fairer, perhaps, to put the blame for the disputes upon them rather than upon the pedantry of George Grenville, or the obstinacy of George III, or the "umbrageousness"—to use Pitt's word—of American extremists.

What were the conditions and circumstances which made Grenville's position so difficult? The *first* was the *want of unity*, due to historical conditions, of the thirteen American Colonies which stretched along the American seaboard. They were of different origin, different occupations, even different climates. Their patriotism was local and confined to one Colony; and there were continually disputes between the Colonies as to their respective boundaries. "Fire and water," said a traveller in 1760, "are not more heterogeneous than the different Colonies in North America." As a consequence all attempts—and attempts had been made, as, for instance, in 1754—to get the Colonies to combine for defence had failed; and the Mother-Country had had continually to interfere to settle boundary questions and disputes with the Indians.

The *second* condition which involved difficulty was the old colonial system. Great Britain had not worked out satisfactorily in detail the principles which should control the relations of the Mother-Country and the Colonies; and these relations had developed in somewhat haphazard fashion. Perhaps Great Britain was to blame for this, but, after all, that is her British method, and there is a great deal to be said for it: and even now in 1920 we have not got a rigid system. Let us take, as an example, in the eighteenth century the three most important departments of Defence, Trade and Government—in all of which danger of friction lurked.

In Defence, Great Britain did far more than her share. She was wholly responsible for naval defence; she provided convoys, protected the Colonies from the French, Spaniards, and not least the pirates.[1] She kept garrisons, chiefly at her own expense, in the danger spots; she gave arms and ammunitions to the Colonies for local Indian wars. Finally, in time of war she assumed the chief burden.

Then in Trade. The old idea of historians was, in the words of Sir John Seeley, "that Mother-Countries regarded Colonies as merely estates out of which the

[1] *British Colonial Policy*, 1754–65, by G. L. Beer (1907); *American Colonial Government*, 1696–1765, by O. M. Dickerson (1912). Of earlier writers Lecky's chapters, written soon after 1880 in his *History of England in the Eighteenth Century*, are a triumph of impartiality.

[1] We had an arrangement, for instance, with the Barbary pirates in the Mediterranean by which they left immune the ships of Great Britain and her Colonies. When the American Colonies became free, the Barbary pirates, by their captures, quickly reminded the Colonies of the more unpleasant aspects of independence!

Mother-Country was to make a pecuniary profit." But recent historians have taken a much more favourable view of Mother-Countries in general, and of Great Britain in particular. Thus Mr. G. L. Beer, the American historian, has put forward a good case in his attempt to show that the primary object of the British colonial system was to develop the wealth and power of the Empire as a whole, and to make it self-sufficing. The system was based on mutual reciprocity; it was, as the French called it, "Le Pacte Colonial." It was, for instance, a grievance, perhaps, to the American Colonies that they were only allowed to send their tobacco to England. But, on the other hand, Englishmen were only allowed to smoke Virginian tobacco; and when in 1661 Gloucester, Worcester, and Herefordshire tried to grow tobacco plants of their own, British troops were sent to destroy them. Perhaps England in the various arrangements was a little selfish and got rather the better of it. The making of hats in America, for instance, was forbidden owing to the Company of Hatters in London getting the Government to act; and great care was taken to prevent competition in the Colonies with the woollen exports that came from England. And it was certainly an aggravation that all goods from Europe to America had to go via England. But, at any rate, the English system was more liberal than that of any country. Moreover, the Colonies seem to have acquiesced in the system, though of course there was grumbling on particular points. Finally the Colonies evaded certain of the regulations by systematic smuggling; and you never could get a Colonial jury to convict a smuggler any more than you could in Sussex or in Scotland.[1] Both in the trade regulations however, and in their evasion, dangers lurked of which we shall say something later.

Then with regard to the Government. The details varied in each Colony. But, speaking generally, we may say that each Colony had a Governor, either appointed or approved by the Crown. The Governor was supposed to carry on the administration; he possessed a veto on legislation as did also the Crown at home—a right which the Crown seems to have used, not indeed unfairly but freely, as a total of 400 laws disallowed in 100 years indicates. Each Colony had a Council, a sort of Upper House nominated or approved by the Crown; and an elected Assembly with power of taxation. Now between 1700 and 1750 a remarkable transformation had occurred in the government of the Colonies. If the first half of the seventeenth century saw the successful fight for self-government in England, the first half of the eighteenth century saw

[1] A man was charged with smuggling soap from Ireland direct to Jamaica; and the jury decided it was a foodstuff, and hence legal, because one witness said a man could live on soap for a month!

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a no less successful fight for self-government in the American Colonies.

"By 1765," says Mr. Dickerson in his recent book, the nominated Councils "had been robbed of their chief legislative powers, judges and other officers had become dependent upon the Lower House; the Governors had been reduced to inefficient figureheads, dependent upon the Assemblies for their daily bread, and impotent to obey the orders they received from England. There are few stories more fascinating than the account of this gradual subversion of the old colonial constitution by our stubborn forefathers, and the substitution in its place of a Government which could be controlled independent of the Mother-Country." A Governor depended for his own salary, and for those of his various officials, on the popular Assembly; he had to consult the Speaker of that Assembly upon nearly all measures, and had to take his advice if he wished things to go smoothly. The Speaker became, in fact, almost the local Prime Minister. No doubt there were grievances. The power of veto was one; the deficiency and corruptness of some of the Governors sent from England was another; the slowness of communications and the dilatoriness of the Home Government was another. But when all is said, the Colonies were, as regards Government, in a far more favourable position than any other Colonies at that time in the world; and far more independent than the territories—or colonies—which the United States themselves controlled in later years!

The situation, then, in 1765 was a system of Defence which left too much to the Mother-Country; a system of Trade regulations which, from its very nature, was difficult to work fairly; and a system of government in which the American Colonies had obtained, through their own efforts, a position of independence which they were not at all likely under any circumstances to surrender.

The *third* feature which made matters difficult was the Seven Years' War.[1] That war had, owing to the genius of the elder Pitt, seen magnificent successes—Hawke and Boscawen had won two memorable sea victories at Quiberon and Lagos; Wolfe had won Canada on the Heights of Abraham; the English infantry had won the Battle of Minden on the plains of Germany. The Battle of Plassey had made us king-makers in Bengal, that of Wandewash had ruined the French ambitions in Southern India. But nevertheless that war was largely responsible for the loss of the United States. In the first place, by giving us Canada it had freed the English Colonies from the French danger; as Mr. J. R. Green put it years ago, "With the victory of Wolfe on the Heights of Abraham began the history of the United States." It is quite unfair, of course, to suggest that the Colonies were conscious that they could now rebel in safety; but the point of importance is that, when the difficulties did arise, they were able to take a far stronger position because they no longer required the help of the Mother-Country against the French. Secondly, the war had left England burdened with an enormous debt, very heavy taxation, and no security for the future, as it was known that France and Spain were preparing for revenge. And at the end of every war, as at the end of the Great War we have just been engaged on, comes the cry for economy. The largeness of the national debt makes people talk of national bankruptcy, and there is an unwillingness to incur fresh obligations. That was the situation of England in 1765, as in 1920.

And then came the *fourth* circumstance which brought matters to a head. There was a great rising of the Indians under the formidable Pontiac along the frontiers of Pennsylvania and Virginia. The country for twenty miles inside the frontier over a long distance was completely desolated and several forts were lost. The position was very critical. Eventually, after a long conflict of fourteen months, the revolt was put down, chiefly by British forces. The Colonies, owing to their want of unity and various jealousies, had done badly. Massachusetts, for instance, had refused to help at all; Connecticut with great reluctance had sent but 250 men. The failure of the Colonies to combine, and the possibilities of future difficulties with the Indians, forced the British Government to the conclusion that they must keep an army of 10,000 men in America. But the question at once arose who was to pay for that army? Would Great Britain, with her heavy debt and her prospect of future wars and her already undue burdens in the way of defence, undertake the whole cost of an army designed solely for the defence of the American Colonies? Could the Colonies, disunited as they were, be got to agree on some system whereby they should be responsible for part of the expense? If the answer to both these questions was in the negative, would the Colonies, flushed with success in the struggle for self-government and now free from the French menace, submit to taxation imposed from outside? Obviously the problem was a difficult one—how George Grenville dealt with it and how he ought to have dealt with it will be the subject of discussion in a second article.

[1] The Seven Years' War (1756–63) was fought, it will be remembered, between Great Britain and Prussia on the one side, and France, Austria, and Russia on the other; and towards the close of the war Spain joined France and her allies.

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Roman Trade Societies

By E. V. Arnold, Litt.D.

Professor of Latin in University College, Bangor

THE history of past times always offers a rich field for discovery. Sometimes new records are disinterred, or old ones for the first time interpreted, as in the case of the arrow-head inscriptions on bricks or the palaces and temples of perished cities. More often discoveries are made by the combination of existing material; and this is particularly the case with the Roman Empire of the imperial period. Over great areas of Europe, Africa, and Asia Minor have been found scattered thousands of inscriptions bearing witness to the Roman civilisation of the time; and we have voluminous law books from which information of the same kind may be collected. Chiefly from these sources we are now able to reconstruct the history of Roman trade societies over many centuries, and even to trace in this connection a progressive development which seems to contain some elements of inevitability. The story of the trade societies may be said to reflect the whole history of the rise and decay of Roman civilisation.

We hear of certain societies or guilds in the earliest days of Rome; these are the so-called "colleges" of musicians, goldsmiths, dyers, tailors, tanners, coppersmiths, and potters. All these are travelling trades, and stand contrasted with the agricultural labourers and those who practised home industries.

The latter groups were sufficiently organised in the patriarchal household, with its family discipline and its daily religious observances. The musicians, dyers, and so forth felt the need of constructing some kind of family system amongst themselves. The first step was to select a protecting deity, such as Mercury or Minerva; the next to institute at least an annual festival, in which the honouring of the god was joined to the enjoyment of his worshippers. Thus the societies were concerned with religious and social interests, and only indirectly promoted the material advancement of the members of each trade.

For all that they were at first regarded with suspicion by the Roman Government, as possible centres of disorder or revolution. And, in fact, they played a considerable part at election times, at which an organisation always counts for more than an individual. Several times laws were passed to suppress the societies altogether, but they were never effective. When Octavian established monarchy at Rome after the Battle of Actium in 31 B.C., one of his first public acts was to place the colleges under control. He therefore required that each particular college should obtain authorisation from the Senate; for which it would need either to

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show that it was of ancient foundation, or that it served important public needs. From this time all societies existed by favour; and numerous inscriptions show us that the favour was eagerly sought. But that the societies still used their influence for political purposes appears from the inscriptions which still cover the walls of the disinterred city of Pompeii, of which a great number consist of appeals issued by trade societies on behalf of their favourite candidates.

The laws of the Roman Empire were not very strictly administered, especially as regards the working classes, and numerous colleges were formed without the permission of the Senate. From time to time efforts were made to repress these unlicensed colleges, but in the end a general licence was granted to all societies of poor men, who might meet once a month and make a monthly collection. Amongst the societies thus formed a great number were burial clubs: these aimed at purchasing burial sites, and maintaining upon them a temple, and often also halls for meeting or dining.

Throughout the first two centuries of the Christian Era the trade societies continually increased in number and importance, and the State learnt to rely upon them for the performance of all duties essential to the prosperity of the community, and in particular for the transport and distribution of food. During this period the societies maintained a voluntary character, and were essentially self-governed.

The inscriptions reveal to us with fair completeness the inner organisation of the society. The members might be "ordinary" or "honorary"; the latter did not necessarily belong to the trade of the college, but joined out of sympathy. In small towns two or more trades would combine to form one society. Ordinary members were usually elected by the general meeting, but sometimes by the committee; they had to pay an entrance fee. They were then formed into groups of about ten members, called "decuries"; each group was subject to a group-officer, or "decurion." In the larger societies ten decuries (roughly) were formed into "centuries" under the command of a "centurion." This form of organisation is clearly borrowed from that of the Roman army.

The supreme authority rested with the general assembly (*conventus*). It held regular meetings at fixed dates, and special meetings when called by the president. It made the rules of the society, controlled the administration, and fixed the dates of festivals; it supervised the finance, and authorised the setting up of statues and altars with their inscriptions. It elected its own officers, except that certain societies had electoral committees (*censores*), to which they deputed this duty.

The chief officer was called president or master (*magister*); the number of such officers varied from two to six, and they took turns in performing the duties of the office—that is, in presiding at the general meetings, and generally in guiding the affairs of the society. Although the humblest member might rise to be president, it was usual to select a man of means for the office. He might be expected to pay a substantial fee upon his installation, to give the members a banquet, or to present a statue or a building. Besides the president there were the trustees (*curatores*), the treasurer (*arcarius*), the secretary (*scriba* or *tabularius*), the marshals (*viatores*), and the chaplain (*sacerdos*).

In public celebrations all these officers were overshadowed by the "patrons" or "patronesses," men and women of high rank who interested themselves in the societies' affairs, and sought popularity and influence as a return for their public-spirited efforts. Naturally the most numerous and wealthy societies secured the most eminent patrons: so that, whilst all the societies were in principle organisations belonging to the humbler classes, there was amongst them every gradation of importance and wealth. Some of these societies had considerable landed property, and imposing buildings and burial-grounds; others struggled for a bare existence, and perished from time to time by the desertion of their members. All, so long as they maintained their existence, gave to the man who individually was humble and helpless the sense of security and importance in his corporate capacity.

But the time came when the State not only guaranteed the corporate existence of the necessary societies, but made membership of them compulsory on all citizens. Alexander Severus (about A.D. 230) prescribed that all men throughout the empire should be compulsorily enrolled in their respective societies. If their numbers were thus increased, their inner strength decayed. Compulsion was used because the societies were growing too weak to discharge their duties; and the root-cause of this weakness was the shortage of men throughout the empire. It was felt in every rank of society; and each order and profession therefore took steps to conserve its membership; and since each was associated with a particular town, the first step was to prohibit migration. Membership of a college thus became a burden instead of a privilege. If members escaped, it remained possible to confiscate their property; and so gradually all property was considered as belonging to the society, not to the individual. To recruit new members, sons were bound to the trade which their fathers had followed before them. The tighter the bonds, the more frequent were the efforts made to escape from them: men fled from the towns to the mountains and the desert to escape from their duties.

Thus the life of the towns became completely dis-

organised; in the country-districts the change was less violent. Landowners offered refuge to the runaway townsmen on condition of service, and they were glad to accept a position which was practically that of serfs attached to the soil. But the landed estates could offer no resistance to the invasions of the barbarians; and the friendly societies, after a century or more of decay, finally perished in the general fall of Roman civilisation

The city-life of the Roman Empire in the third and fourth centuries A.D. has some analogies to the ideal of the Socialistic State. Certainly every trade was under State control, and its direct purpose was the prosperity of the city; and at the same time proprietors and employers were deprived of all profits, and in fact became poorer year by year. But the analogy must not be pressed too far; the centuries referred to are those of the general decline and fall of Roman civilisation, of which the direct causes were war, famine, and pestilence. The experience goes to show that State control of industries is not a panacea for every national or social evil; but we hardly know enough of the circumstances to judge whether, in fact, it proved a mischief or a support to the tottering empire.

But if we look back to the two preceding centuries, we find in the societies the happy outcome of a widely diffused sentiment of sympathy and humanity. There is no indication that the societies were at any time a nursery for class hatred, and they were not for any long period centres of political disturbance. The rich and the poor, the free and the slave, met within these organisations on a temporary equality; and gaiety and good-fellowship prevailed at their monthly assemblies. There is perhaps something for us to learn from these experiments in the past; and the early history of the Christian community cannot be rightly understood till it is recognised that it was in its beginnings one friendly society amongst many others.

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engineers. He was trained in Chemistry at Manchester, and worked subsequently under Professor Haber at Karlsruhe in Germany. During the war he was on the research staff of the Ministry of Munitions, and his chief work for this body was in connection with the production of ammonia from the elements nitrogen and hydrogen which compose it. This is the basis of a process of great importance, and it is largely due to his technical and executive ability that a sure foundation for the future development of this industry in this country has been laid.

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Before the war the knowledge of the average man with regard to poison gases was not an extensive one. Poisons were associated in his mind with the chemist's shop, the extermination of rats, a post-mortem at Hoxton, or with a murder case at the Old Bailey. Prussic acid was the best known. The young man blighted in love raised the phial of this accursed drug to his lips, and so deadly was its vapour that he passed over, as the Spiritualists say, ere his lips came in contact with the liquid. East-end practitioners, bothered by bibulous charwomen in their surgeries, kept their whisky in large green bottles labelled "Prussic Acid." (Such is a practical use of scientific knowledge!)

The only poison gas commonly known was the domestic sort, which certainly had a detrimental effect on the system when (in absence of a lighted taper) it was turned full on in a badly ventilated room.

But the war has changed all this. The Germans made use of poison gases as a weapon of war, the Allies retaliated, and a new art of warfare, the science of gassing, came into being. To Dr. Haber, whose work on gases gained for him the Nobel Prize in Chemistry of last year, much of the development of this art is to be ascribed.

The first use of poison-gas in warfare was made in April 1915. The gas used was chlorine. This gas was liquefied behind the line in large heavy cylinders. These were carried into position by perspiring Teutons, and disposed at regular intervals along the line. At a given signal, on a day of favourable wind, the gas was released among our men. The result we knew. There was great indignation at home, because this act was clearly and blatantly at variance with the terms of the Hague Convention, but in France among our men there was even greater anger. Emergency respirators of a kind were rapidly improvised, but many thousands of our men were killed by the gas, and many of the survivors suffered most terrible agonies. These first respirators were merely pads of material tied round the mouth, not unlike what a Dickensian character might wear if he were suffering from a sore throat or a badly stopped tooth on a cold day. They were more effective when moistened, but they were not a striking success.

We ourselves began to use gas in September 1915. It was a great secret, and it was so well kept that the first intimation many of us had of our intention to use gas came from those at home who were serving their country by making it. About this time many artillery units found themselves digging numerous small dug-outs in the front line, just sufficiently large to accommodate "a general and one staff officer." Most units set to work without putting any but a literal interpretation on this somewhat extraordinary order. These dug-outs were for the accommodation of our cylinders of chlorine.

At the same time there appeared a new brand of brothers in the Corps of Royal Engineers. They were nicknamed the Coloured Corporals, partly because of the armlet of many colours which they wore, and partly because the lowest rank in the company was that of Corporal. These men were for the most part excellent chemists in private life, but in war their duty was to handle the heavy cylinders of chlorine (familiarly termed Roger), and to release the gas at the required moment. Many an infantryman or gunner, watching these men, felt glad that at school chemistry had not been in the curriculum.

But the use of cylinders of poison gas was open to many

objections. The cylinders were not only very cumbersome, but they were extremely vulnerable. (They went off when struck by an enemy shell, even though they weren't manufactured for that purpose.) In addition the opportune discharge of gas depended on the slope of the country in front of the front line, and on the shape of the trenches and on the direction and velocity of the wind. Even then, after much palaver over the 'phone, and the alteration of the zero hour because of "conditions," the discharged gas not infrequently did some harm to our own troops as they went over to the attack.

In consequence shells, trench-mortar bombs, and even hand grenades were filled with poison, and then fired into the enemy's midst. These had no back effect, and so long as they fell approximately at the chosen spot they were effective.

For success in attacking by gas, one of the most important things was to maintain a high concentration of the poison in the air around. One part of a gas in a thousand of air when maintained was considered a high concentration, and indeed one part in ten thousand with most poison gases was quite effective. One would imagine that the denser the gas the more deadly it would be, other things being equal, because it would lie in trenches and in shell-holes where soldiers were; but it must be remembered that all poison gases soon became very diluted by the air round, and the density of the mixture therefore, after a time, could not be very different from that of air itself.

What did the scientific organiser of gas warfare consider to be the most important features of a gas? First of all, the ease with which the necessary large quantities of the gas could be made, and the convenience with which it could be transported; secondly, the effect of the gas when inhaled by the soldier, and the difficulty the other side might have in providing adequate protection against it.

The best known of the gases used were chlorine, phosgene, mustard gas, and chloropicrin, but many more, described by long chemical formulæ and even longer chemical names, were used by both sides. The element of surprise was an important tactical point, and it was considered clever to send over a new gas of which the other side was ignorant, and against which they had provided their soldiers with no protection.

Chlorine, as everyone knows who has inhaled it, even in small doses, has a most irritating effect on the throat and lungs. It is, however, a simple and honest poison. You may see it coming, and so avoid it. Further, either you get it or you don't get it. With phosgene, on the other hand, you are never quite sure where you are. Although its effect is less irritating than chlorine, it has a delayed physiological action.

[*Continued on p. 60*

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It may be breathed apparently with impunity, but the trouble comes later.

Chloropicrin was one of the chief lachrymators or weeping gases, and was used effectively, even at a concentration of one part in a million, against troops doing any work in which weeping rather interfered with things. Mustard gas was an irritant which even in very small amounts had a very inflammatory effect on the skin, the more insidious because it was not immediate. It produced serious sores at the parts affected, notably on the eyes, leading to many cases of permanent blindness, and to an enormous number of cases of temporary blindness.

These are the best known, but more irritating and more deadly gases were being experimented with towards the end of hostilities. It is rather curious that prussic acid, which is associated in most minds with sudden death, was used so little. The reason for this is that, except in large concentration, its effect is very mild. Also it is a very simple gas to secure protection from with a respirator.

The first respirator issued to our troops after the original mouth-pad had been superseded, consisted of a flannel helmet with mica eyepieces, which was pulled over the head and tucked in under the collar. Impregnated in the flannel was a solution of "hypo" and other materials for absorbing the chlorine. Later patterns of this type were provided with glass windows for the eyes, and a rubber valve for exhaling the breathed air. After a time a box respirator was introduced, and this completely superseded the helmet type. This respirator consisted of a small box filled with granules of specially prepared charcoal, which was guaranteed to absorb nearly every kind of poison gas known. It was connected with the piece that covered the face by a flexible rubber tube. A clip gripped the nose in a most convincing manner. The breathing in and out was done through the mouth by means of suitable valves.

It was a simple device, comfortable enough, and everyone who was in France had the pleasure of drilling in it. It gave complete protection against most of the poison gases used, and when the charcoal deteriorated it could be easily replaced.

It is the opinion of a speaker at the last meeting of the British Association that poison-gas warfare is not so inhuman as it is commonly supposed to be. The argument was, that granted that human beings must die or suffer so that military objects may be gained, then such objects may be attained by the use of poison gas with less loss of life and permanent injury than by the employment of high explosives.

We agree, but we hope that this type of warfare is ended for ever.

A. S. RUSSELL.

Correspondence

METEORIC SHOWERS AND COMETS

To the Editor of DISCOVERY

SIR,

Though the practical identity of certain meteoric systems with comets has been an acknowledged fact for more than half a century, there are not more than six instances which may be said to have been demonstrated fully. This meagre result is due to several causes, the chief of which are that (1) comparatively few comets revolve in orbits which intersect the earth's path or pass sufficiently near it to occasion a shower of meteors; and that (2) observational data are scanty, for students in this branch of astronomy have rarely applied themselves to the special purpose of discovering new instances of meteoric and cometic identities. Yet if more attention were directed to this part of the subject, there is no question that our knowledge might be considerably extended.

There are doubtless many cases where meteor and cometary orbits exhibit mere chance agreements, but were the observations more abundant and accurate, it would be possible to select those entitled to confidence as representing true accordances. It is to be hoped that this department will receive more earnest attention in future years.

On October 22 of last year a fireball was seen at Bristol and at other places by various good observers. It had a long horizontal course of about 335 miles from the North of England to the South of France. Its radiant point was at 156°+39°. Now the comet of 1739 has a radiant point at 157°+39° on October 22 according to computations made by the late Prof. A. S. Herschel. Here is a possible case of a meteoric fragment from a cometary system. The writer has seen, in and since 1877, other meteors from the same source, and it seems a fair inference that these objects owed their derivation to the comet named. In some cases no doubt the visible meteor showers allied with comets may be extremely feeble, and incapable of furnishing exhibitions of the brilliant and abundant character of the Perseids of August and Leonids of November, but they are none the less interesting, and deserve fuller investigation.

W. F. DENNING, F.R.A.S.

BRISTOL,
January 16, 1920.

Reviews of Books

Outlines of the History of Botany. By R. J. HARVEY-GIBSON. (Black, 10*s.* net.)

Professor Harvey-Gibson has given us the substance of a course of lectures which he delivered to his students in the University of Liverpool. It is an account and a discussion of the more important features in the advances of botanical knowledge from the earliest times down to the present day. Now this is the kind of book we like. It gives us an interest in a subject without our having to pass an examination prior to our imbibing the facts. On us a textbook has a stand-and-deliver effect, but a history is always genial and kindly. It admits us to the subject at once. There is no waiting in a queue or fumbling for cash at the door. We go right in—"on the nod," it is true—but we get in, and no unpleasant questions are asked.

The general reader has more leisure for the study of the history of a subject than the ordinary University student. The latter is compelled by his examiners to pursue the policy so warmly advocated by Mr. Gradgrind, and go in for Facts, and consequently, in a present-day University curriculum there is little room for the pleasant occupation of studying the history of a scientific subject.

Professor Harvey-Gibson, in this excellent book of his, points out, however, that a proper estimate of the relative values of the results achieved by investigators in the past, leads to a picture, in correct perspective in the mind of the reader, of the evolution of the science as a whole. It is an antidote to narrowness of view and to premature specialisation. There are some people who dislike History just as there are some Scots who dislike England. They do not see the point in getting to know what Linnæus (for example) thought of such-and-such a subject in the year 1686. To them it is as irrelevant as the old pantomime gag, "What did Mister Gladstone say in '74?" Besides, you only get five marks for the history question in the examination!

But this is a wrong view. In the history of any subject there are always two interests: an interest in the subject-matter itself, and a more human interest in the men who overcame the difficulties in developing their subject. One may be interested in Botany without caring a fig for a fig-tree, but the point not to be overlooked is, that this interest may lead to a deeper one. And so it comes to this: Does the history tend to make one long to study the subject more, and join in the work of development oneself, provided the necessary ability is capable of being produced? If the history of a subject were the record of an infallible past, it would never stimulate the worker to be up and doing. He would be in the same plight as the research-worker who complained bitterly that all the obvious things in his subject had long ago been discovered. But such history, if it be properly written, reveals not only success and wonderful achievement, but also failure, error, and even crass stupidity. And it is because of this that we, duffers, and yet at the same time remarkably fine fellows, believing ourselves akin to the great men of the past, are constrained to take heart and carry on the work which their genius initiated.

Ions, Electrons, and Ionising Radiations. By J. A. CROWTHER, Sc.D. (Arnold, 12*s.* 6*d.* net.)

Dr. Crowther explains in his preface that his book is neither a popular exposition of the "new Physics," nor is it an account in short compass of the whole subject. It is a book from which students who have studied the physics of the ordinary textbook, may obtain a systematic knowledge of the latest developments in certain definite branches of the subject. The book deals chiefly with the phenomena connected with the discharge of electricity through gas, with X-rays, and with radiations from radio-active substances. The older books of J. J. Thomson, Rutherford, Townsend, and Bragg on special portions of modern physics are, of course, the authoritative ones, and are indispensable to those who are, or intend, undertaking new work. Dr. Crowther, by choosing carefully the most important portions of the work dealt with in the larger volumes, and by bringing the subject-matter up to date wherever that is necessary, has written a most useful exposition of the subject. His book is suitable for all those who have had a good grounding in physics and mathematics, and who have neither the unlimited time nor the pelmanised brain necessary to follow, in the original papers, all the wonderful developments of the latest work.

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